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Resource Manual for Implementing the NSPS Continuous Monitoring Regulations. Manual 1 - Source Selection and Location of Continuous Monitoring Systems

Acurex Corp., Mountain View, Calif.

Prepared for

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RESOURCE MANUAL FOR IMPLEMENTING THE NSPS CONTINUOUS MONITORING REGULATIONS

Manual 1 - Source Selection and Location of Continuous Monitoring Systems

Stationary Source Enforcement Series

EPA-340/1-78-005a
April 1978

U.S. ENVIRONMENTAL PROTECTION AGENCY
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Manual 1 - Source Selection and Location of Continuous Monitoring Systems - is one of a series of four manuals that comprise the "Resource Manual for Implementing the NSPS Continuous Monitoring Regulations." The other manuals are:

Manual 2 - Preliminary Activities for Continuous Monitoring System Certification (Installation, Notification and Performance Evaluations)

Manual 3 - Procedures for Agency Evaluation of Continuous Monitor Data and Excess Emission Reports

Manual 4 - Source Operating and Maintenance Procedures for Continuous Monitoring Systems

Manual 1 presents NSPS regulations for selecting and locating opacity and gaseous monitors for affected sources. Specific problem areas such as stratification, dilution, water vapor interferences and multiple feed points, are discussed. Criteria for selecting monitoring systems and checklists for agency inspection and review of equipment installations are included.

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by

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A. INTRODUCTION

Manual 1, Source Selection and Location of Continuous Monitoring Systems, of the "Resource Manual for Implementing the NSPS Continuous Monitoring Regulations" presents all NSPS regulations for selecting and locating opacity and gaseous monitors for affected sources. In addition, the regulations have been presented in a form that will be of practical value to the observer and the affected source operator. Specific problem areas such as stratification, dilution, water vapor interferences and multiple feed points, are discussed.

Since a good observer must have an understanding of the operating principles of opacity and gaseous monitors, this Manual contains discussions and schematic diagrams of the most common types of monitors in use today Discussions of criteria for selecting monitoring systems, equipment provisions for Agency observation and a referenced checklist are also included.

Manual 1 is one of a series that comprise the "Resource Manual for Implementing the NSPS Continuous Monitoring Regulations." The other manuals are:

Manual 2 Preliminary Activities for Continuous Monitoring System Certification (Installation, Notification and Performance Evaluations)

Manual 3 Procedures for Agency Evaluation of Continuous Monitor Data and Excess Emission Reports

Manual 4 Source Operating and Maintenance Procedures for Continuous Monitoring Systems

B. MONITOR SELECTION

1. Regulations

The regulations for selecting monitoring equipment are found in the subparts of Part 60 that deal with specific classes of sources. These regulations do not specify a certain brand of monitor or a specific operating principle. In most cases, the regulations specify the emission to be monitored and identify the Performance Specification that the continuous monitoring system must meet. In addition, they specify the reference method required for the performance evaluation, the applicable span value of the instrument, and the data conversion approach.

a. Regulations Affecting Selection of Monitoring Equipment

Table 1-1 presents a summary of the NSPS regulations which will have an effect on which continuous monitor a source may select.

b. Regulations Affecting Selection of Data Handling Equipment

Although the regulations do not place particular requirements on the data recorder component of measurement systems, many requirements do affect the selection of a data recorder, the operating procedures to be used, and the way recordings are read and reported. In describing apparatus, most subparts of Part 60 include general statements on data recorders. For example, 60.152 (amended) Paragraph 19, Appendix B, Paragraph 2.2 reads:

> Data Recorder. Analog chart recorder or other suitable device with input voltage range compatible with the analyzer system output. The resolution of the recorder's data outputs shall be sufficient to allow completion of test procedures in this specification.

More specific data recorder requirements are also included in Part 60 Appendix B - Performance Specifications. For example, Paragraph 4.3 reads:

> Data Recorder Output. The continuous monitoring system output shall permit expanded display of span calibration on a 0- to 100-percent opacity scale.

And 60.45(a) contains the following statement:

> --- the continuous monitoring system shall be spanned at 80- or 90- or 100-percent opacity.

Since the data recorder is a subsystem of the continuous monitoring system, there are general performance specifications for the analyzer, interface, and recorder. The relevant portion of the definition of a continuous monitoring system is in 60.2(y):

> "continuous monitoring system" means total equipment... to analyze, and to provide a permanent record of emissions or process parameters.

TABLE 1-1. SUMMARY OF NSPS REGULATIONS AFFECTING SELECTION OF CONTINUOUS MONITORING EQUIPMENT

Source Category	Affected Facility	Federal Register Reference	Pollutant	Span Value	Calibration Gas	Performance Test Reference Method
Steam generators	Oil fired boilers	60.45(a)	Opacity	80 - 100%	–	–
		60.45(b)(1)	SO_2	1000 ppm	SO_2	Method 6
		60.45(c)	NO_x	500 ppm	NO_2	Method 7
	Gas fired boilers	60.45(c)	NO_x	500 ppm	NO	Method 7
	Coal fired boilers	60.45(a)	Opacity	80 - 100%	–	–
		60.45(b)(1)	SO_2	1000 ppm	SO_2	Method 6
		60.45(c)	NO_x	1000 ppm	NO_2	Method 7
	Liquid/solid mix Fired boiler	60.45(a)	Opacity	80 - 100%	–	–
		60.45(b)(1)	SO_2	= 1000y + 1500z[a]	SO_2	Method 6
		60.45(c)	NO_x	= 500 (x+y) + 1000z[a]	NO_2	Method 7
	Fossil/non-fossil Fuel fired boiler	60.45(a)	Opacity	80 - 100%	–	–
		60.45(b)(1)	SO_2	subject to Administrator's approval	SO_2	Method 6
	All boilers	60.45(d)	O_2 or CO_2	90% of span calibration gas or air if >21%	O_2 or CO_2 in N_2 or air midrange and 90% of span	Method 3
Nitric acid plants	Process equipment	60.73(a)	NO_x	500 ppm	NO_x	Method 7
Sulfuric acid plant	Process equipment	60.83(a)	SO_2	1000 ppm	SO_2	Method 8
Petroleum refineries	FCC catalyst regenerator	60.102(a)(1)	Opacity	60 - 80%	–	–
		60.102(a)(3)	SO_2	100 ppm	SO_2	Method 6
Electric arc furnaces	–	60.273(a)	Opacity	none	–	–
Primary copper smelter	Dryer	60.165(b)(1)	Opacity	80 - 100%	–	–
	Roaster, smelting furnace, copper converter	60.165(b)(2)	SO_2[c]	0.20% by volume[b]	SO_2	Method 6

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[a] x,y and z equal the fraction of total heat input derived from gaseous, liquid and solid fossil fuels respectively.

[b] During the performance evaluation, the span of the continuous monitoring system may be set at a sulfur dioxide concentration of 0.15 percent by volume if necessary to maintain the system output between 20 and 90 percent of full scale.

[c] The continuous monitor is used as the compliance test method.

TABLE 1-1. SUMMARY OF NSPS REGULATIONS AFFECTING SELECTION OF CONTINUOUS MONITORING EQUIPMENT (Concluded)

Source Category	Affected Facility	Federal Register Reference	Pollutant	Span Value	Calibration Gas	Performance Test Reference Method
Primary zinc smelter	Sintering machine	60.175(a)	Opacity	80 - 100%	–	–
	Roaster	60.175(a)(2)	SO_2[c]	0.20% by volume[b]	SO_2	Method 6
Primary lead smelter	Blast furnace Dross reverberatory Furnace sintering Machine	60.185(a)(1)	Opacity	80 - 100%	–	–
	Sintering machine.	60.185(a)(2)	SO_2[c]	0.20% by volume	SO_2	Method 6

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[b]During the performance evaluation, the span of the continuous monitoring system may be set at a sulfur dioxide concentration of 0.15 percent by volume if necessary to maintain the system output between 20 and 90 percent of full scale.

[c]The continuous monitor is used as the compliance test method.

Part 60 specifies a minimum number of data points rather than an integrated average to compute average emissions rates. Since most of the processes affected have continuous production, the readings or samples can be relatively infrequent.

> 60.13(a) --- all continuous monitoring systems shall be in continuous operation and shall meet minimum frequency of operation requirements as follows:
>
> (1) --- for measuring opacity of emissions shall complete a minimum of one cycle of operation (sampling, analyzing, and data recording) for each successive 10-second period.
>
> (2) --- for measuring oxides of nitrogen, sulfur dioxide, carbon dioxide, or oxygen shall complete a minimum of one cycle of operation (sampling, analyzing and data recording) for each successive 15-minute period.

For opacity, readings are averaged over a 6-minute period. For other pollutants, readings are averaged over a 1-hour period or combination of 1-hour periods.

> Section 60.2 definitions:
>
> (r) one-hour period means a 60-minute period commencing on the hour.
>
> (x) six-minute period means any one of 10 equal parts of a 1-hour period.

Other time periods are specified for particular sources. For example, Subpart D: Standards of Performance for Nitric Acid Plants Section 60.73: Emission Monitoring:

> (e) For the purpose of reports required, 60.7(c), periods of excess emissions that shall be reported are defined as any 3-hour period during which the average nitrogen oxides emission (arithmetic average of any three continuous 1-hour periods) as measured by a continuous monitoring system exceeds the standard under 60.72(a).

The required frequency of reporting, units of measurement, and other process parameters to be reported may also influence the selection of a data recorder and data reduction method.

2. Major Equipment Types and Operating Principles

The major types of continuous monitoring equipment and their basic operating principles are described briefly below. A thorough review of all available instrumentation is not within the scope of this manual. However, the Lawrence Berkeley Laboratory of the University of California (Berkeley) published a two-volume study* of available instrumentation which is updated periodically. This document should be referred to for more specific information.

a. Opacity Monitor Principles

Systems for monitoring opacity are based on the principle of transmissometry, or directly measuring the attenuation of visible radiation (light) caused by particulate matter in a stack effluent. Light with specific spectral characteristics (visible wavelengths) is projected from a lamp across the stack into a light sensor. The particulate matter absorbs and scatters the light beam, decreasing the intensity seen by the sensor. The amount of attenuation of the light beam is defined as the opacity of the emission. Transparent stack emissions which do not attenuate visible light will have a transmittance of 100 or an opacity of 0. Opaque stack emissions which obscure all of the visible light from the source will have a transmittance of 0 and an opacity of 100 percent. Since the transmittance is a function of the path lengths, transmittance must be adjusted to the stack exit diameter.

Typical opacity monitors on the market are usually either "single" or double-ended" systems. In the single-ended system (dual path) (Figure 1-4), the light source, sensor, and all electronics are located in a single unit on the side of the stack. the light beam is sent, then reflected from the opposite side of the stack by a mirror, making two passes through the stack. Since the complete system is on one side of the stack, it is relatively simple to make differential as opposed to absolute measurements of light intensity. Voltage variations, detector variations, and electronic drift are all cancelled out in the differential measurement.

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*Instrumentation for Environmental Monitoring - AIR, May 1, 1972, Environmental Instrumentation Group, LBL, University of California, Berkeley, CA 94720.

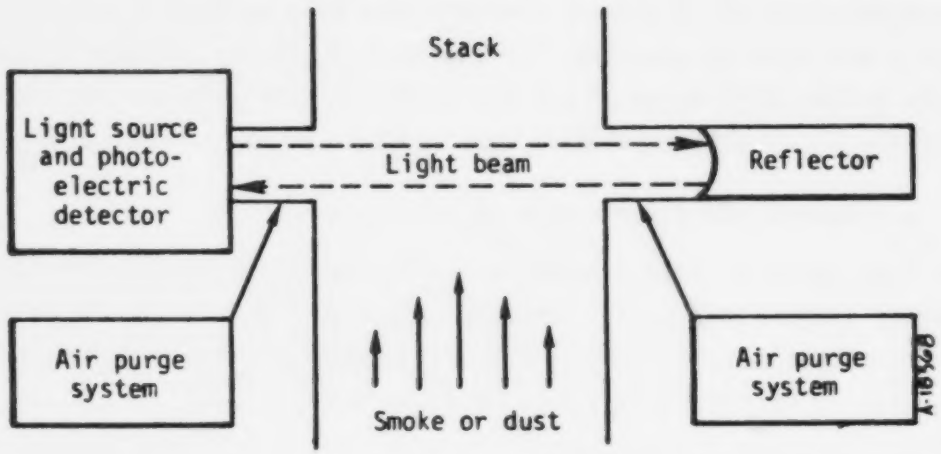

Figure 1-4. Single-ended opacity monitoring system.

In a double-ended (single path) system (Figure 1-5), the light source and detector are on opposite side of the stack and the light travels once across the stack. These types of transmissometers are inexpensive and have been popular throughout the last 35 years. However, because of their alignment sensitivity, difficulty in zero and span calibration, and sensitivity to voltage and light variations, many of these monitors cannot be used for EPA monitoring purposes. Since they are inexpensive, they will probably be useful as simple warning devices, indicators of poorly performing control devices, etc., where quantitative accuracy is not most important. However, some manufacturers of single-end monitors meet NSPS by using a method that creates a zero opacity condition for the full light beam in order to obtain absolute online calibration of all the optics on both sides of the duct. This method also employs a slotted mounting pipe to maintain alignments.

b. Gaseous and Diluent Monitor Principles

Many varieties of equipment currently are available for continuously monitoring gaseous pollutants. However, after sorting out all the publicity, there are only four or five major types of equipment. The operating principles used in each major type are discussed below.

(I) Ultraviolet Absorption

The nondispersive ultraviolet analyzer shown in Figure 1-6, is a split-beam photometer. It monitors the concentration of a pollutant by measuring the difference in the amount of radiation absorbed at two different wavelengths (in the ultraviolet and visible). Radiation from the light source, usually a gas discharge lamp, is partially absorbed as it passes through a sample of gas. As radiation leaves the sample, it is divided in two beams by a semitransparent mirror. Each beam then passes through an optical filter which removes all wavelengths except the one to be measured. The filtered beam then strikes a phototube.

The beam splitter is set up to reflect and transmit so that the intensities of the radiation striking each phototube will be nearly equal during normal operation of the analyzer.

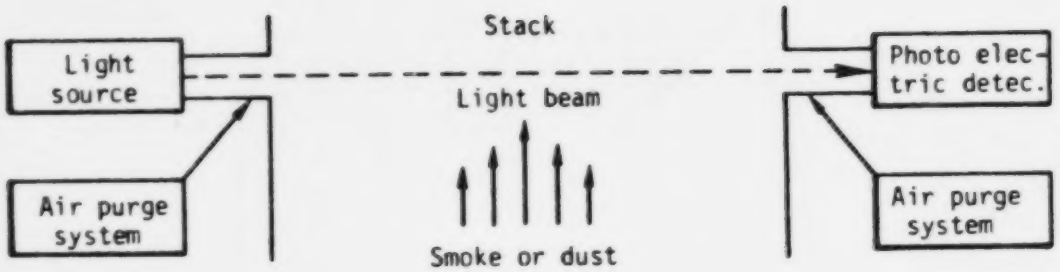

Figure 1-5. Double-ended opacity monitoring system.

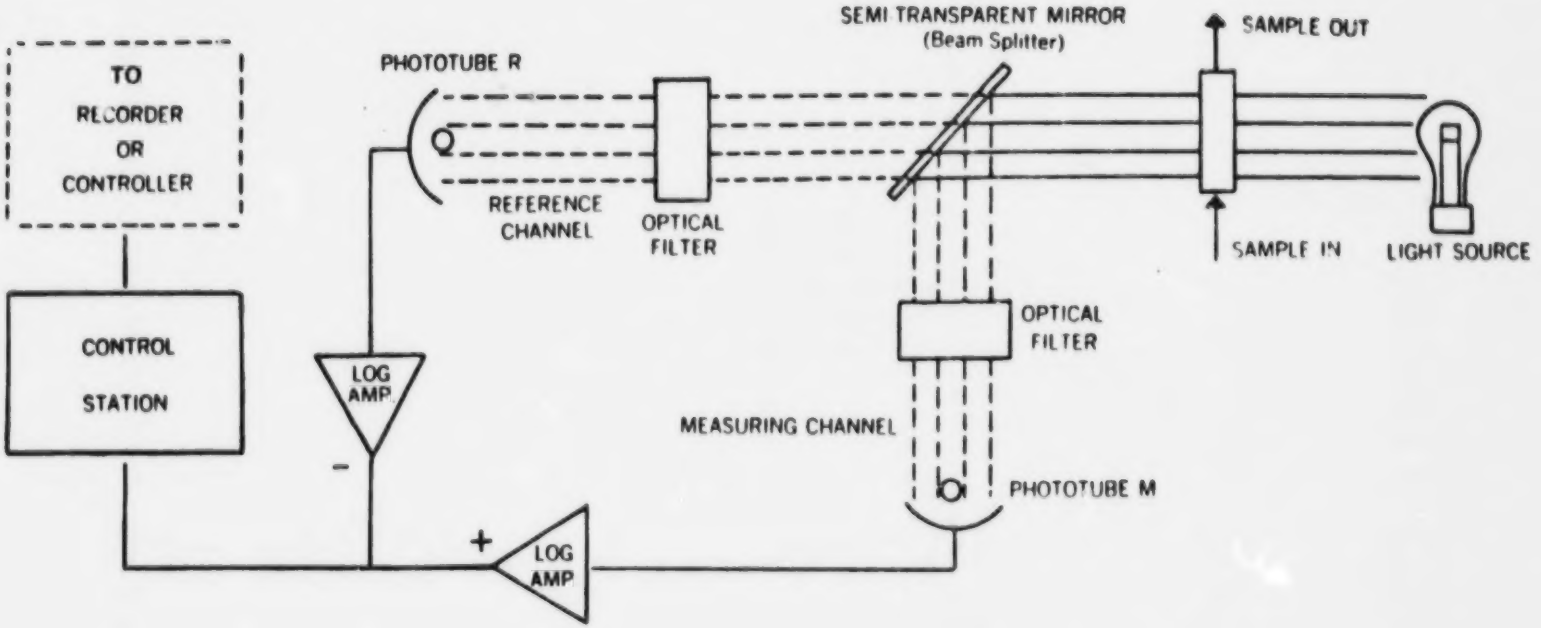

Figure 1-6. NDUV analyzer.

The beam reaching one phototube is in a wavelength which is absorbed strongly by the pollutant being measured; thus, this beam actually measures the concentration. The beam directed to the second phototube is in a wavelength which is absorbed weakly or not at all by the pollutant and is used as a reference. If the concentration of the absorbing pollutant changes, the intensity of radiation reaching the first phototube varies in accordance with the Lambert-Beer law. The radiation to the second phototube varies very little, or not at all.

In each phototube, the current flow is proportional to the intensity of radiation striking the phototube. This current is fed to an amplifier that outputs a dc voltage that varies logarithmically with the current and, hence, with the intensity of the radiation. Voltage output from the reference beam amplifier is subtracted from that of the measuring beam amplifier. This difference in voltage output varies linearly with the concentration of the pollutant being measured.

Nondispersive UV analyzers are somewhat more sensitive than nondispersive infrared (NDIR) analyzers and are not subject to the interferences (e.g., H_2O, CO_2) that affect NDIR analyzers. Nondispersive UV analyzers for measuring SO_2 may have interference from NO_2; however, this interference can be filtered out electronically.

(II) Infrared Absorption

Two main types of infrared sensors commonly used are nondispersive and dispersive. The term "nondispersive" refers to the lack of a light-dispersing element, such as a prism or grating that selects a particular analytical wavelength of light. The traditional Luft-type nondispersive infrared (NDIR) analyzer has been used to make process and environmental measurements for over 20 years. A schematic of this type of analyzer is shown in Figure 1-7.

In the NDIR analyzer, two identical infrared-radiation emitters serve as matched sources of broad-band infrared energy. Radiation from these sources is modulated by a motor-driven chopper disk and passed through filers and measuring cells into an energy receiver. The reference cell is filled with a gas, such as nitrogen, that does not absorb infrared energy. Another

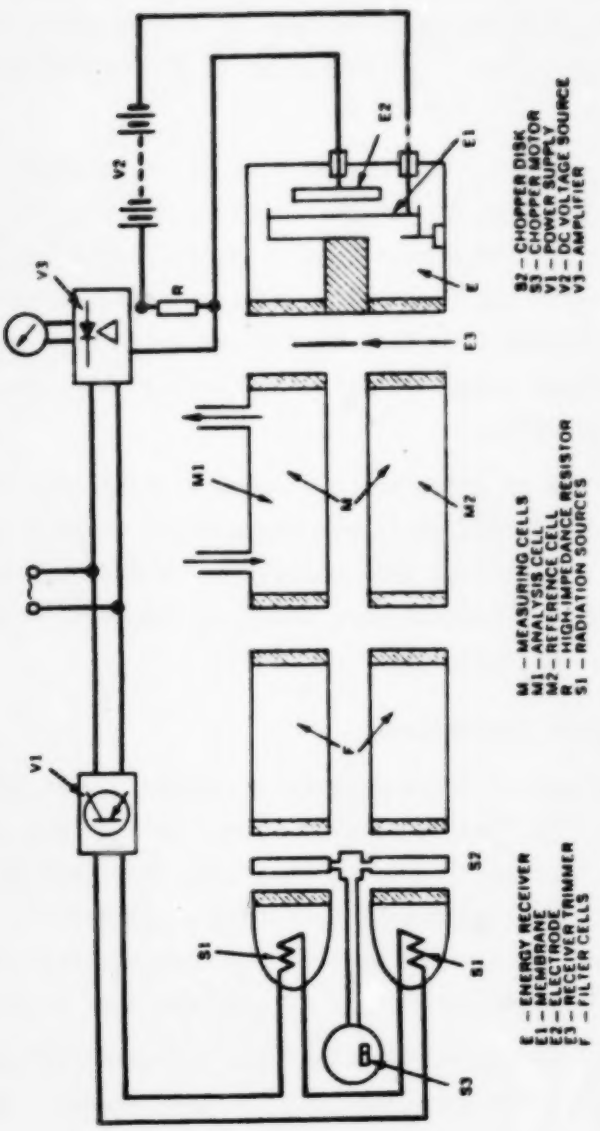

Figure 1-7. NDIR analyzer.

cell contains the gas being analyzed. The amount of infrared energy passing through the analysis cell that will be absorbed by the gas depends on the concentration and wavelength band of the gas.

The energy receiver consists of two chambers separated by a membrane. Both chambers are filled with mixtures of the gas to be measured. As the gas absorbs infrared energy, it heats up and pressure increases. If the two chambers are exposed to equal amounts of energy, the membrane will remain in a neutral position and there will be no output from the instrument. However, since the gas in the analysis cell absorbs more energy, pressure on that side of the chamber increases and the membrane deflects. This deflection is detected as a change in electrical capacitance between the membrane and a fixed electrode and, therefore, as a change in ac voltage at a resistor. This ac voltage change is displayed as dc current using a measuring amplifier on an indicating instrument.

If the gas to be tested contains components with absorption bands that slightly overlap those of the pollutant being measured, identical filter cells are filled with the interfering components to screen them out. This "positive filtering" makes it easier to measure the pollutant.

The Luft-type NDIR analyzer generally uses an extractive sampling system to transport the sample of stack gas to the analyzer. Particulate matter and water vapor that interfere with the species measurement are removed. Generally, Luft-NDIR analyzers are used to monitor SO_2, CO and CO_2.

A schematic of another nondispersive analyzer is shown in Figure 1-8(a). In contrast to the Luft-type analyzer, which looks at a broad spectral region and which must be sensitized for each particular gas using a detector cell, this NDIR spectrometer can be set at any wavelength within its range. In addition, unlike the Luft-type analyzer, the adjustable analyzer is not limited to a single, preselected gas. However, when many absorbing gases are present, it may be difficult to locate a wavelength in a spectral region where other gases do not absorb.

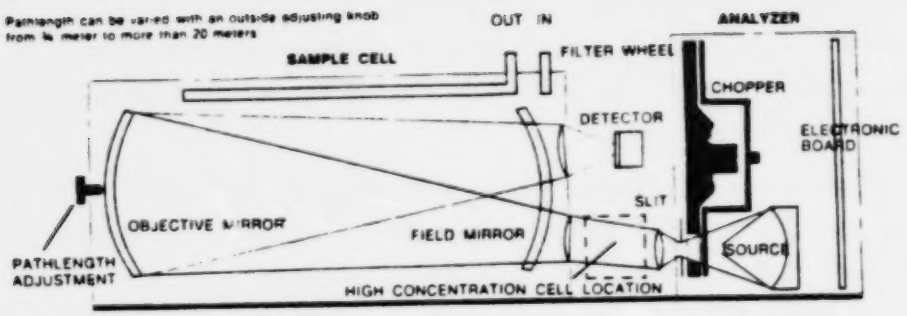

Figure 1-8(a). A variable wavelength NDIR analyzer.

The analyzer shown in Figure 1-8(a) uses a narrow-band pass filter which scans the spectral region between 2.5 and 14 microns. It could be used, for example, to measure SO_2, which has an absorbance maximum at 7.4 microns. Since it has a variable pathlength from 3/4 to 20 meters, the analyzer has a large sensitivity range. This and similar analyzers can measure many gases simultaneously. However, other gases, water vapor, or particulates may cause absorption problems in the spectral region of the pollutant.

Another type of nondispersive infrared analyzer is the gas cell correlation spectrometer shown in Figure 1-8(b). EPA researchers are investigating this type of analyzer as an in situ analyzer for various pollutants. The analyzer uses a broad band IR source and detector and one or two cells filled with varying concentrations of the gas to be measured to provide the wavelength selection. This technique has shown potential for rejecting interference. Thus, it can be used to improve low level sensitivities, or to simplify or eliminate requirements for sampling systems. In addition, by switching selection cells, several pollutants can be monitored by the same unit.

Figure 1-8(c) shows a single-beam, dual wavelength nondispersive infrared analyzer. In this analyzer, a single IR radiation beam is passed through the sample gas and filtered into two wavelengths by a chopper. The wavelengths are chosen so that one wavelength has no absorption, while the other has maximum absorption. The ratio of their absorptions is sensed by a conventional thermoelectric IR detector.

The dispersive infrared analyzer (Figure 1-8(d)) uses a broad band IR radiation source and a broad band detector similar to the gas cell correlation and filter-type analyzers. However, the wavelength is selected by using a prism or diffraction grating which physically disperses the light at different angles. Light at 7.4 microns (a typical SO_2 wavelength) may be deflected at 22.2°, whereas light at 4.3 microns (CO_2) may be deflectd only 9°. By placing sensitive detectors at the proper positions, several components can be measured concurrently, limited only by the space available. However, this approach has several drawbacks. First, the analyzer's ability to select a specific wavelength depends on the angle and length of the dispersing

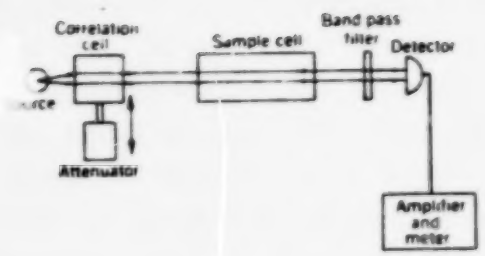

Figure 1-8(b). Another nondispersive analyzer.

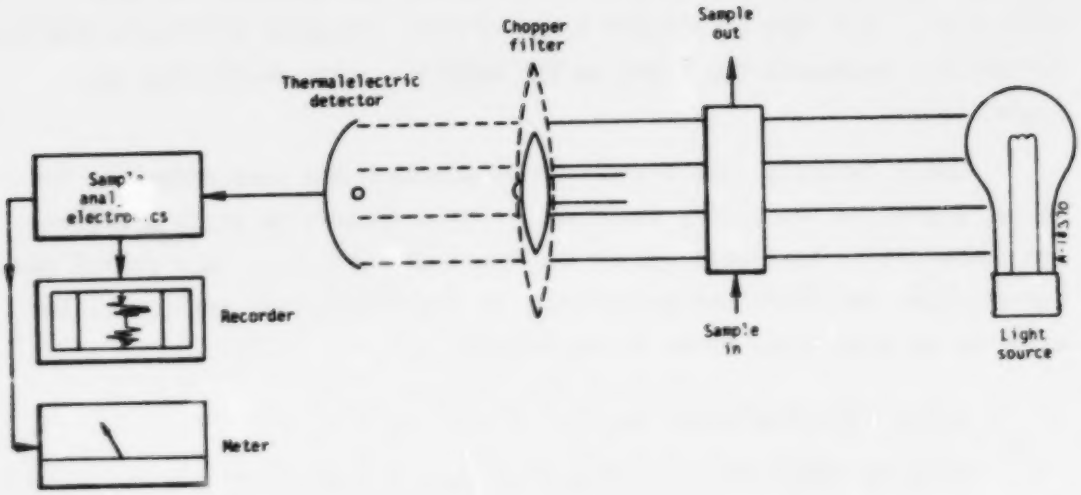

Figure 1-8(c). Single-beam, dual wavelength NDIR.

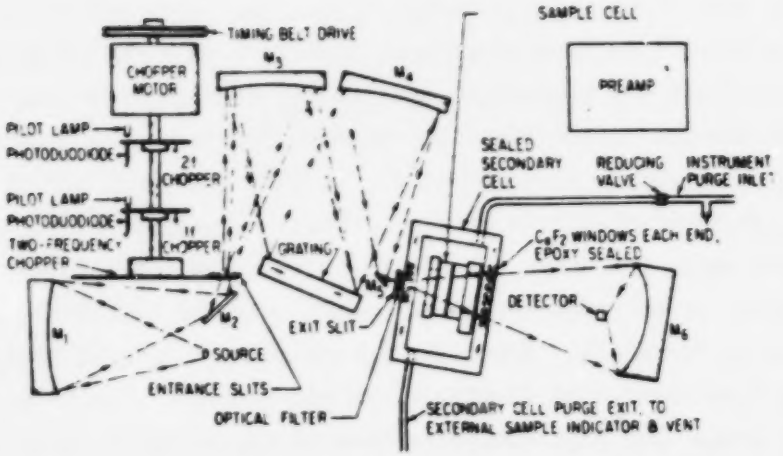

Figure 1-8(d). A dispersive IR analyzer.

path (L). To be very selective, it is necessary to use very long paths (a meter or two) or a very narrow slit or mask on the detector for good resolution. But long pathlength makes optical alignment difficult, and the narrow slit decreases the light to the detector, thus decreasing the signal level.

Until recently, the dispersive IR approach was used primarily for large, expensive laboratory equipment. While dispersive stack analyzers are commercially available, other new types of analyzers, such as the gas cell correlation, the new chemiluminescent, or the fluorescent analyzers, are expected to play major roles in the future.

(III) Chemiluminescence

Although NDIR analyzers have been used to measure nitric oxide (NO) for 20 years, chemiluminescence has been used in approximately 90 percent of the installations since it was introduced commercially. This is true even though chemiluminescence is two or three times more expensive.

Chemiluminescence is a chemical and optical monitoring technique. In this technique, a gas molecule reacts with a reagent to form an excited molecule that spontaneously decays, producing photo-emissions. Sensitivity, rapid response time, and instrument stability make the chemiluminescence method suitable for continuous monitoring, although care must be taken to maintain the monitored stream at constant flowrates. A typical NO and NO_x analyzer is shown in Figure 1-9(a). In this analyzer, NO molecules combine with O_3 to form an excited molecule (NO_2). A photomultiplier detects photo-emissions decay and sends the signal to a sample-and-hold circuit. To detect NO_2, an NO_2 to NO converter is connected into the gas stream and the NO analysis is run again. After the second pass, a circuit subtracts the first reading from the second to obtain the NO_2 reading. Few interferences have been observed, but high concentrations of CO_2 or water vapor may partially quench the chemiluminescence. In addition to monitoring NO and NO_x, chemiluminescence devices are also used to detect O_3.

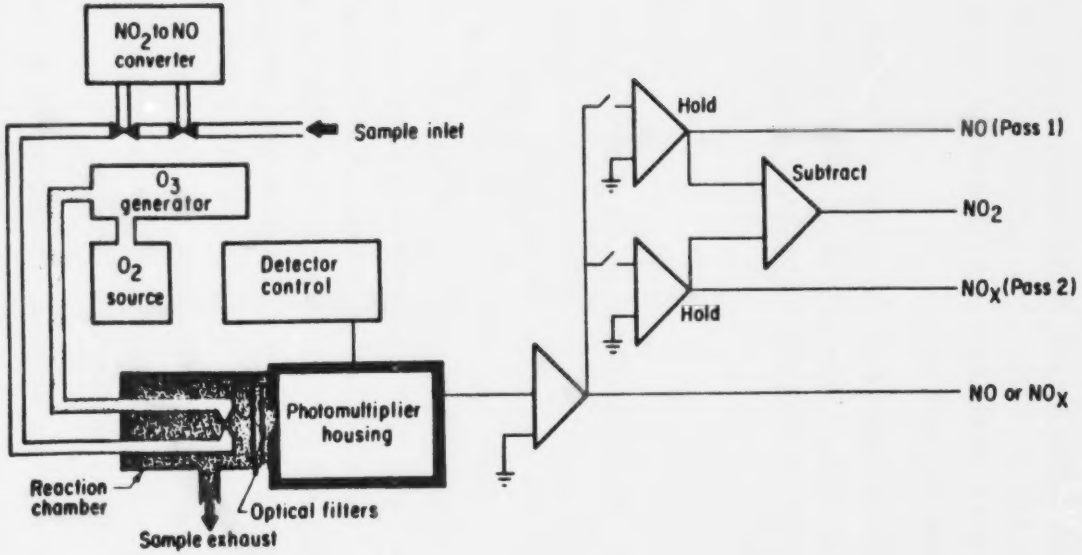

Figure 1-9(a). Chemiluminescent analyzer.

Other gas molecules, such as carbon monoxide and sulfur dioxide, have also been measured by fluorescence (Figure 1-9(b)). In the fluorescent analyzer, as in the chemiluminescent analyzer, the gas molecules are excited to a higher energy level, and their photo-emissions during decays are measured. However, where the chemiluminescent analyzer uses a chemical reaction to produce the excited molecule, the fluorescent analyzer irradiates the gas molecules with a pulse of light. The pulsed, ultraviolet fluorescence SO_2 analyzers recently introduced into the market may be as successful as the chemiluminescent NO_x monitors.

As with chemiluminescence, fluorescence analysis is highly specific and has few interferences. However, since high concentrations of CO_2 and water vapor may partly quench the fluorescence, most units use some type of water vapor removal.

(IV) Electrochemical

Analyzers using electrochemical transducers measure the current induced by the electrochemical oxidation of the pollutant at a sensing electrode. Sensors are available for measuring O_2, SO_2, CO, H_2S, NO, and NO_2. Figure 1-10 shows a simplified schematic of an electrochemical transducer. In this analyzer, the pollutant diffuses through the semipermeable membrane into the transducer at a rate proportional to the concentration. At the sensing electrode, the pollutant undergoes an electrochemical oxidation or reduction which causes a current directly proportional to the partial pressure of the gas being monitored. Since electrons are produced at the sensing electrode, this electrode is at a lower potential than the counterelectrode. Thus, an electron current can flow from the sensing electrode through the amplifier to the counter electrode, and the current will be proportional to the concentration of the pollutant.

Selectivity of the transducer is determined by the semipermeable membrane, the electrolyte, the electrode materials, and the retarding potential. This potential is adjusted to retard oxidation of species that are less readily oxidized than the pollutant of interest.

Selecting a specific chemical compound for measurement is not always possible. For example, the SO_2 sensor is sensitive only to SO_2, but the

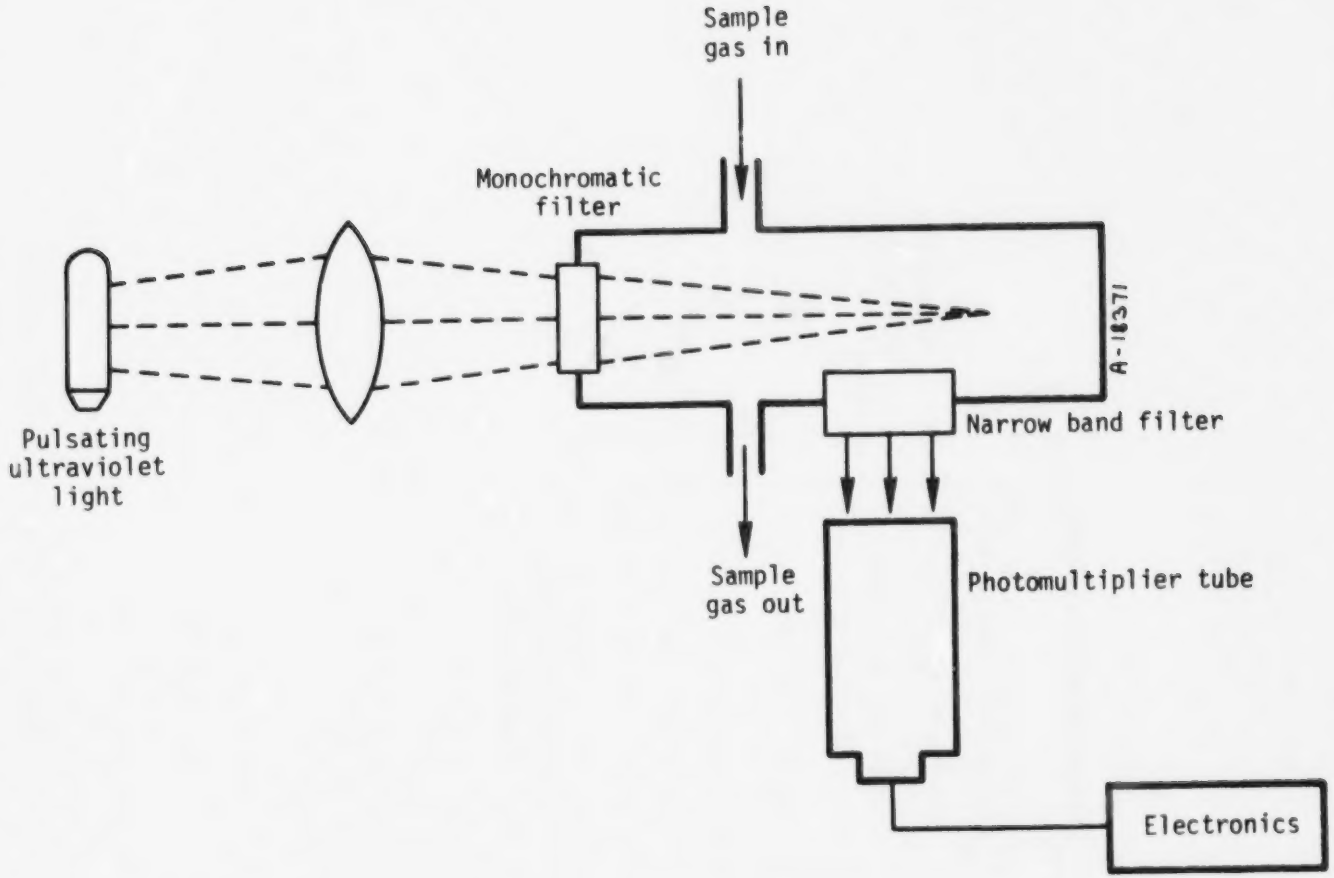

Figure 1-9(b). Fluorescence analyzer.

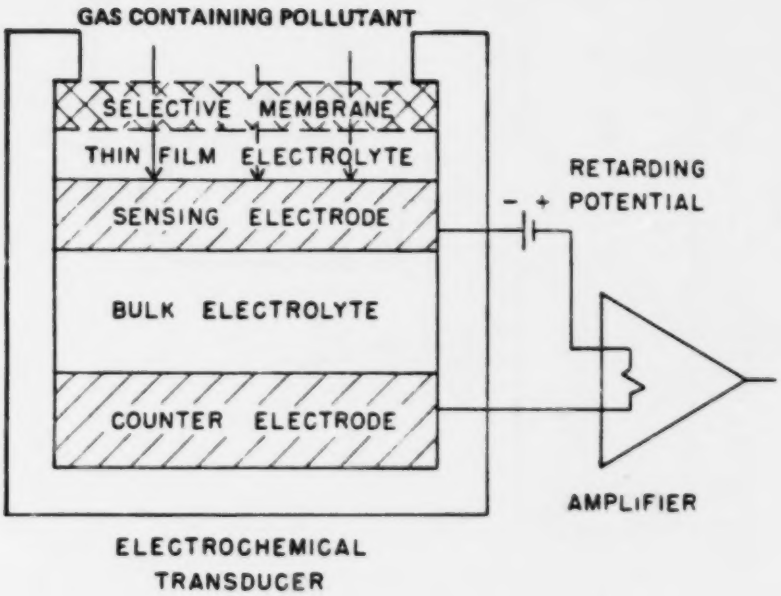

Figure 1-10. Electrochemical analyzer.

NO_x (NO-NO_2) sensor is also sensitive to SO_2. Thus, SO_2 in the gas stream must be removed with a scrubber solution, or measured by another sensor and cancelled out electrically. Electrochemical sensors have been used primarily in portable instruments for quick spot checks of pollutant concentrations, although several vendors offer continuous source monitoring systems based on these sensors.

(V) Paramagnetic

Very few gases are paramagnetic, oxygen being one. Analyzers for oxygen, using this principle, have no particular advantages or disadvantges over other types, such as the electrochemical analyzer. They do, like most other types of analyzers, require a clean (particulate-free) and dry sample.

In one model paramagnetic analyzer, a test body suspended on a platinum-iridium wire in a nonuniform magnetic field experiences a torque proportional to the magnetic susceptibility of the gas surrounding the test body. The torque is counteracted by an opposing torque produced by passing a current through a coil around the test body. By means of a light source reflected from a mirror mounted on the test body, and a differential photocell and amplifier, the current is continuously and automatically maintained at the value needed to balance the initial torque. This current is thus proportion to the magnetic susceptibility of the sample gas. The output is not affected by the density of thermal conductivity of the sample gas or by any catalytic effects. Errors caused by variations in other sample gas components are small and predictable.

3. Monitoring System Selection Criteria

In choosing a monitoring system for a specific source, both economic and technical factors must be considered. Economic considerations include costs for installation, calibration, maintenance, data processing, and the overall system. Technical considerations include the ability to measure and record accurately for a particular source, the levels and types of interferences present, sample and ambient temperature and pressure extremes, accessibility of sample locations, and availability of maintenance personnel. Sources of information on these monitoring systems are plentiful.

a. Prior Experience of Users and Agencies

Several groups within EPA have evaluated prototype and commercialized monitoring systems on a number of sources. These studies have been widely distributed through meetings, papers, and reports. Reference 8 summarizes some of the more useful EPA and industrial reports that are readily available. These reports are referenced at the end of this section.

The earlier reports (1971-1973) show that the monitoring equipment then available generally performed adequately when equipped with a good sample conditioning system. Unfortunately, at that time good sampling systems were sold by only one or two vendors. Subsequently, both vendors and the EPA began to develop better sample conditioning systems, as well as systems that do not require sample conditioning (in situ or new extractive).

In opacity monitors the window purge system constantly blows clean air on optical windows to minimize particulate fouling. EPA has found that the overall design of the window purge system is one of the major differences between opacity monitors that operate correctly and those that do not. Most commercial vendors with field experience in installing monitoring systems now have an adequate sampling system that will operate correctly if maintained properly. If a vendor is willing to give several references (companies using his equipment on a particular source), chances are good that his system will operate correctly, if properly maintained, for that type of source. However, potential customers will do well to follow up on these references.

In all monitoring systems, the key words are "if properly maintained." Almost every problem found by EPA over the last 2 years was related to lack of daily checks and weekly maintenance. Typically, a monitor would encounter a minor problem such as a plugged filter, a stuck valve, or a closed shutter would be out of operation until the next scheduled evaluation 2 or 3 weeks later, even though 5 minutes of maintenance would have corrected the problem. Therefore, an effective monitoring program requires daily checking and maintenance.

b. Specific Criteria for Gaseous and Diluent Monitoring Systems

In selecting a monitoring system for a specific plant, several general questions should be answered:

1. What are the concentrations of the pollutants of interest?
   If a facility is normally controlled at 20 to 110 ppm but can upset to 1000 ppm, a monitoring system with a wide range should be used. Furthermore, as previously delineated, the states require some specific performance characteristics. Optical absorption techniques (NDIR, UV, IR), chemiluminescent (for NO_x) and fluorescent (for SO_2) analyzers all have wide ranges. Although some optical absorption techniques have difficulty maintaining linearity over a 20:1 range change, they may be more appropriate at pollutant concentrations in the percentage ranges than chemiluminescent or fluorescent methods.

2. Does the stack have any stratification?
   For gases with severe stratification or other flow problems, an extractive monitor with multipoint probes or a long-path averaging in situ system mounted in the plane of the bend is most effective.

3. Does the source produce high concentrations of water vapor (3 to 8 percent)?
   Most infrared techniques and the pulsed fluorescent technique are adversely affected by high water concentrations in the gas stream. However, the ultraviolet absorption technique is relatively unaffected by water vapor, and, therefore, would be a good choice.

   In addition, when sampling streams with high concentrations of water, care must be taken to prevent water from condensing and causing corrosion in the system. Plastic (PTFE, PVC), stainless steel, or even glass may have to be used in severe cases. To alleviate the problem, early use of knockout traps, dilution, etc. is recommended.

4. Does the gas stream contain a high concentration of particulate? If possible, monitoring locations with high particulate loadings should be avoided. In situ monitors correct for opacity by measuring at a neutral wavelength and adjusting for the net absorption by taking a ratio of the intensity of the two wavelengths. The success of this correction varies among manufacturers.

   Extractive monitors generally remove particulate with a filter at the probe inlet. High particulate loadings usually require the filter to be backpurged more frequently. This in-stack filter is required for final cleanup of the sampled gas.

5. Does the gas stream contain entrained water or other liquid droplets?
   The presence of entrained water droplets, acid mist droplets, etc. can blind filters used for removing particulate. These drops also corrode sample lines and attack valves in extractive systems. To remove excessive quantities of liquid in extractive systems, water traps, dilution, and heating of the stream can be used.

   Theoretically, liquid droplets (acting as particulate to light) should not effect measurements from in situ systems, for reasons discussed in the Subsection 2(d). Most in situ analyzers have optics external to the stack, which makes them particularly beneficial in certain plants, such as pulp and paper mills. However, in some in situ systems in which the optics are exposed to the gas stream, lenses, windows, and mirrors can become coated with liquid.

6. Will multiple sources or emissions points be monitored?
   As mentioned earlier, Section (g) of Part 60.13 permits a single system to be used for monitoring multiple emission points if all sources must meet the same standard and all sources are combined into a common duct. However, even if multiple streams are not combined into a common stream, a single measurement system can still be used. Most extractive measurement systems can be equipped with

multiple sampling probes. Measurements can be made with these probes by automatically switching between them on a time-sharing basis. The approach is acceptable as long as the minimum requirement (i.e., 5 min. for SO_2) one measurement cycle is completed for each measurement point in each sampling period. Effective sample cleanup and conditioning is extremely important where multiple emissions are measured, because the long sample lines increase chances for deposition, condensation, plugging, and corrosion. If an in situ monitor is used, each monitor can measure only the stack on which it is installed. However, multiple systems can easily share a data recording system.

7. Will the temperature and pressure at the monitoring location present problems?

   Temperature and pressure changes can cause problems in systems that measure pollutant concentration by optical absorption in a fixed cell length. Becuase the gas may expand or contract in the optical pathlength, errors of 0.3 percent per °C change in temperature and 1.3 percent per 10 mm Hg change in barometric pressure can occur. The analyzer must be given a sample at a known temperature and pressure or be equipped with compensating circuits to measure these variables and correct for them. Most extractive sampling systems send samples with steady temperature and pressure to the analyzer. However, the Luft NDIR and electrochemical extractive analyzers are more affected by ambient temperature variations than other types of analyzers.

8. Will vibration and line voltage affect the monitor's performance?

   Vibration and line voltage fluctuations will certainly affect the performance of the monitor and adequate precautions must be taken to eliminate these variables. Voltage fluctuations will be a particular problem for magnetic type recorders installed near electrostatic precipitators.

9. Do other gaseous species interfere with the pollutant being measured?

   Pollutants other than that being measured can interfere with certain types of monitors (e.g., NO_x interferes with SO_x electrochemical analyzers, O_2 interferes with pulsed fluorescent instruments). The presence of interfering species should be taken into account when selecting an analyzer.

10. What are the monitoring system output requirements?

    The regulations do not place any particular requirements on the "data recorder" portion of any measurement system except as noted previously and in paragraph 4.3 of Performance Specification 1 (transmissometers). This paragraph requires an expanded opacity display on a standard 0- to 100-percent scale. Most vendors make available a wide variety of data output, display, and recording devices. Figure 1-11 shows a recent advertisement by an opacity monitor vendor. The analog and digital display modules are equipped with alarm indicators and lights that can be set at any level by the plant operators. To insure that positive action is taken when upset or excess emissions occur, sources should consider locating an additional set of alarms and realtime displays in the office of a responsible plant official. Too frequently, because his prime responsibility is to the process equipment rather than to pollution control, the operator in a control room will merely reset or turn off the alarm. Therefore, the operator should set the alarm for a high level of pollutants, but not the highest level permitted. Then, if the alarm sounds, the operator has time to prevent excess emissions from occuring.

c. Specific Criteria for Opacity Monitoring Systems

As with gaseous and diluent monitoring systems, opacity monitoring systems have definite questions which need to be answered before a source can select a specific instrument.

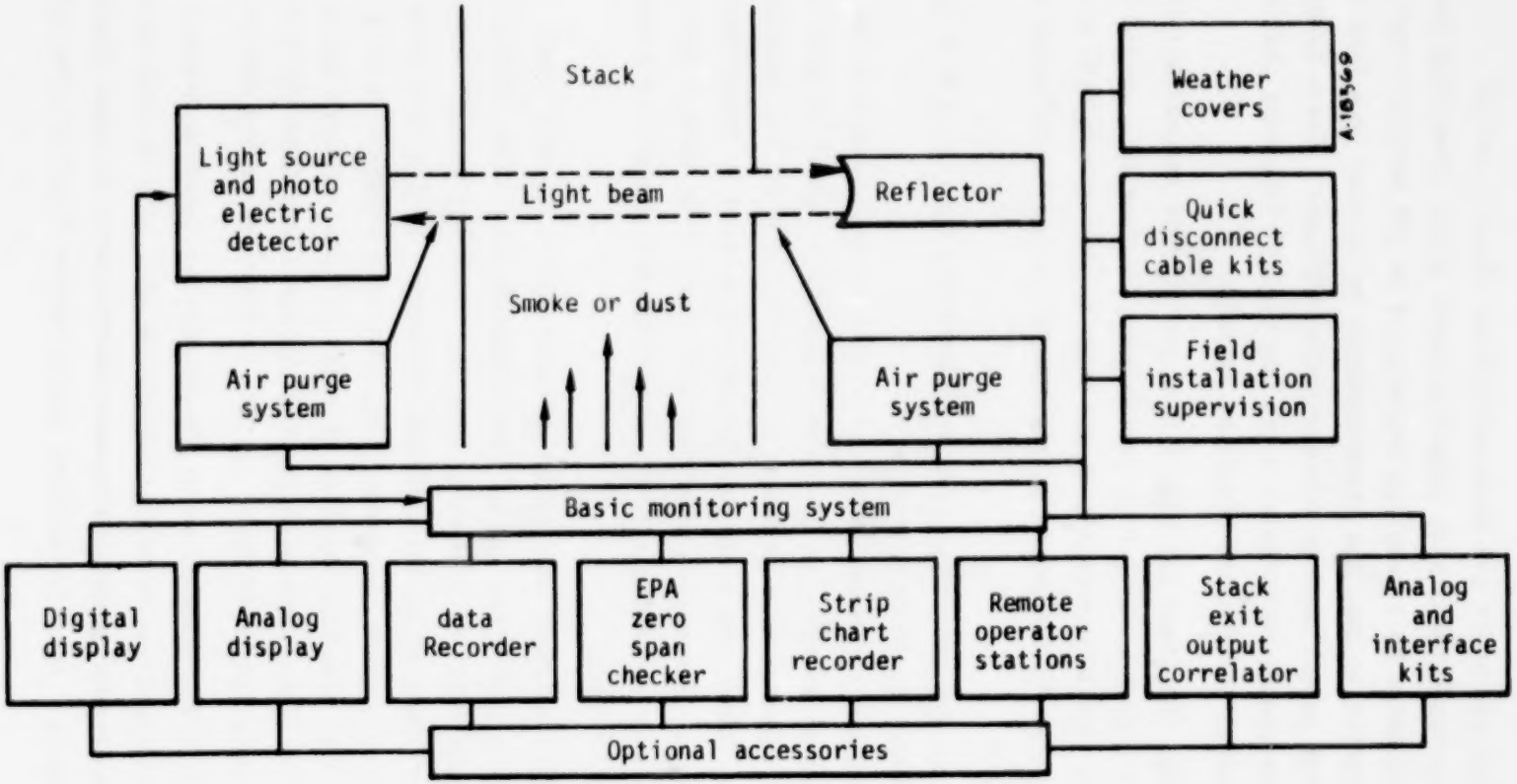

Figure 1-11. Monitoring system outputs.

1. Does the stack gas have particulate stratification?
   For gas streams with excessive particulate stratification (as indicated by a sampling traverse of an EPA Method 5 train), it is imperative that the tranmissometer be located such that the light beam passes through representative effluent. Sharp bends and horizontal rectangular ducts are typical locations that encourage stratification and should be avoided.

2. Does the stack gas have a high particulate concentration?
   If a source has a high particulate loading, they should be certain to install a transmissometer with an adequate optical window purge system - on each end of the optical path if a reflector system is used.

3. Does the gas stream contain condensed water, acid mist or other matter in droplet form?
   Because condensed matter attenuates visible light in the same manner as particulate, transmissometers cannot be used in gas streams of this nature. An alternative mounting location must be found, where the gas stream temperature is above the dewpoint, or an alternative parameter will have to be agreed upon by the source and Administrator to monitor and characterize control device efficiency.

4. Will multiple sources or emission points be monitored?
   If a source has one or more affected facilities subject to the same emission standard, they may install a transmissometer on each effluent or on the combined effluent. If the facilities are subject to different standards, they must have separate opacity monitors. If an affected facility releases effluent through two or more locations, then each one must be monitored separately unless installation of fewer systems is approved by the Administrator.

5. Will the temperature at the monitoring location present problems?
   Fluctuations in stack temperature will have an adverse effect on transmissometer alignment particularly in steel stacks and ducts. Opacity monitors have a narrow field of view and thermal

expansion of steel stacks and ducts caused by load cycling and other non-steady-state conditions will put alignment out of tolerance. Monitors should be adaptable to mounting on a rigid portion of a stack or duct or on a totally independent structure that is not prone to thermal expansion.

6. Will vibration and line voltage affect the monitor's performance? Again, due to the critical optical alignment required by opacity monitors, precautions must be taken to eliminate vibration. Transmissometers will tolerate some voltage fluctuations (typically 115 VDC $\pm$ 10 percent) but a source would do well to eliminate the possibility of severe fluctuations.

7. What are the monitoring system output requirements?
The regulations do not place any particular requirements on the "data recorder" portion of any measurement system except as noted previously and in paragraph 4.3 of Performance Specification 1 (transmissometers). This paragraph requires an expanded opacity display on a standard 0- to 100-percent scale. Most vendors make available a wide variety of data output, display, and recording devices. Figure 1-12 shows a recent advertisement by an opacity monitor vendor. The analog and digital display modules are equipped with alarm indicators and lights that can be set at any level by the plant operators. To insure that positive action is taken when upset or excess emissions occur, sources should consider locating an additional set of alarms and realtime displays in the office of a responsible plant official. Too frequently, because his prime responsibility is to the process equipment rather than to pollution control, the operator in a control room will merely reset or turn off the alarm. Therefore, the operator should set the alarm for a high level of pollutants, but not the highest level permitted. Then, if the alarm sounds, the operator has time to prevent excess emissions from occuring.

d. Maintenance Availability and Requirements

Service and availability of parts for monitoring systems vary widely. Several vendors of monitoring systems maintain nationwide networks of equipment parts and service centers; others provide regional sales offices with a limited stock of parts. Some vendors sell a periodic maintenance program, whereas others will provide the entire monitoring function, including maintenance, data reporting, etc., for a fixed monthly fee.

With one or two exceptions, the vendors would prefer the source owner to assume responsibility for maintenance. In general, a source with an instrumentation shop that can repair process instrumentation such as strip chart recorders, flowmeters, transmitters, and related process instrumentation can maintain a continuous monitoring system. For sources that do not have this capability, the purchase of a complete service package could be highly desirable.

The sources's commitment and attitude will also play an important role in successful monitoring. As mentioned several times before, keeping a system online requires daily functional checks (which should not take more than 15 to 20 minutes). There also must be a commitment to service the monitoring equipment routinely. Unfortunately, such attention is generally not given to nonproductive (frequently perceived as useless) equipment. Furthermore, the equipment must be reasonably accessible to make this commitment more firm. Where possible, emission monitoring equipment should be included in the process control instrumentation that is monitored and logged hourly. In addition, the group that services process instrumentation should service the monitoring equipment. Operators or service personnel should be encouraged to use and benefit from continuous monitors and develop professional responsibility for operating the equipment effectively.

e. Gas Conditioning Requirements

Most extractive continuous monitoring systems require some sample gas conditioning. Depending on the operating principle of the analyzer, particulates, water, and other condensibles must be removed and a particular sample temperature must be maintained. For example, in nondispersive infrared analyzers, particulate matter and water vapor interfere with measuring the

species and must be removed. In addition, condensed water vapor damages internal components and also must be removed.

In some types of industrial processes, if condensed tars from the gas stream are not removed initially, they may form in the analyzer. Also, condensed sulfuric acid mist can cause severe corrosion. For example, in monitoring kraft pulp mills, elemental sulfur can form when sulfur dioxide, hydrogen sulfide, and liquid water react. These problems can usually be solved by a complete sample conditioning system, such as the one shown in Figure 1-12. This system includes particulate removal filters, permeation driers for water removeal, plumbing for purge, span, and calibration gases, and temperature controllers.

f. Selection Criteria of Data Handling Equipment

Again, the regulations have no particular requirements on data handling equipment. In fact, a continuous monitoring system operates perfectly well without one. However, due to the data required to be reported, data handling equipment can be a great aid to affected sources.

Paragraph (c) of Part 60.7 requires that the owner or operator shall report the following information, as well as other information, quarterly: magnitude of excess emission, conversion factor used, the start and stop time of emission and as well as key process and control system data. This data can be collected, utilized and stored automatically. A broad spectrum of equipment and approaches, including different techniques of averaging data, can be used. The simplest approach is to collect the raw data on time-calibrated strip chart recorders. At the end of each month an engineer calculates the emissions for his source, and then tabulates the data into the required report.

A second approach would be to equip the opacity monitor or gaseous monitors with a time-integrating device that calculates the specified average emission value. The integrated value may then be recorded on a strip chart recorder. Paragraph (h) of 60.13 specifies the procedure to be used if an integrating device is included.

A third approach would use one of the automatic data loggers available from several suppliers. These recorders log data, along with the date and

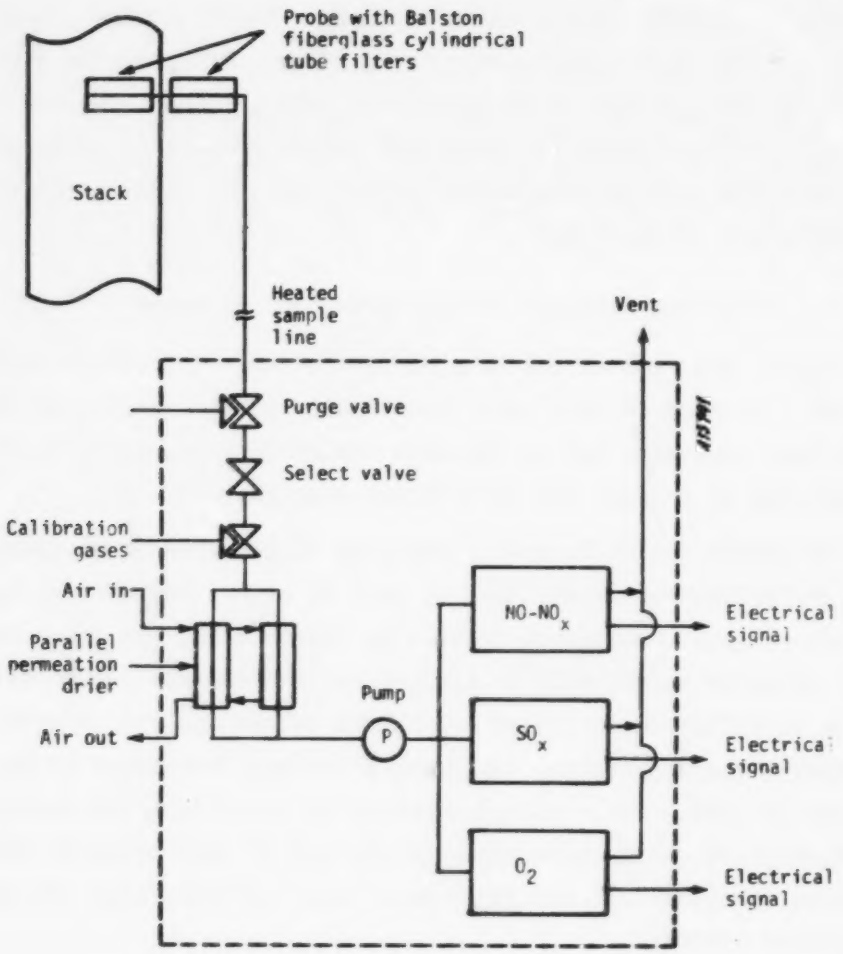

Figure 1-12. Typical analyzer conditioning system.

time, in digital form, on a small 12-column printer. More advanced units incorporate microcomputers which can perform the entire sequence of averaging, timing, calibrating zero and span functions, converting emission factors, and recording data.

These data handling approaches may be adpated for any system or operator functions and procedures. For example, instead of printing out each 6-minute and hourly reading as it occurs, the system may store the data. It will print or display only when readings approach preset limits or excess emission levels, or during calibrations or on demand. Thus, the system can provide a warning system.

Prime considerations in choosing between these approaches are the mean time between failures of teletypes, printers, and recorders and the attention an operator must give to the system, even though it may be operating properly. Automated data loggers can store and process all readings on a central data processing computer or on the process control data acquisition computer. Thus, the data can be further processed, analyzed, and output less frequently. In addition, automated systems can be used effectively when report preparation and data processing from several plants are handled by one center.

Automated, integrating hardware eliminates potential human errors in reading and averaging and decreases the amount of data reduction required later. The reference methods are all based on integrated averages of samples collected over time. In contrast to paper chart data, which is usually visually averaged, most automated data collection systems record instantaneous measurements. Integrated averaging can be added to the strip chart or automated data collection hardware, or included as part of the data reduction. However, in many steady rate processes, the instantaneous reading is a good representation of the integrated average.

The accuracy of the data recorder is inherent in its basic design. The specification for each analyzer will indicate its accuracy. Typically, an accuracy specification of 1/2 or 1 percent of full-scale is satisfactory for use with emission monitors.

The resolution of analog data recorders is inherent in the design of strip chart recorders. Important factors that influence resolution include:

1. Chart width (typically 4-1/2-inch or 10-inch)
2. Chart division (typically 100 divisions full-scale)
3. Chart speed (1 to 4 inches per hour)
4. Type scale (log or linear)
5. Amount of damping

The resolution of digital or multipoint recorders, though not as obvious, is still an important factor in selection. To reduce costs, amplifiers and analog-to-digital (A/D) systems are often shared by several monitors. Thus, the expense of high resolution equipment can be shared. The specifications will indicate the resolution. Important factors include the averaging time and the frequency of analog to digital conversion, typically referred to as the number of counter bits or LSB (Least Significant Bit) of the counter.

For example, the LSB of an eight-bit (28) A/D system is one part in 256. In contrast, a 10-bit A/D has an LSB of one part in 1024. Resolution at full scale for the eight-bit A/D is 1/2 of 1/256 or about 1/2 of $\pm$ 0.4 percent, whereas the 10-bit resolution is 1/2 of 1/1024 or about 1/2 of $\pm$ 0.1 percent.

NOTE

More than four display or print characters (numerals) and/or decimal places will not increase the resolution of even the 10-bit A/D system (which has maximum count of 1024).

Using the wrong combination of equipment can degrade accuracy and resolution. For example, if an analyzer with 0- to 1-volt otuput is connected to a 0- to 5-volt recorder, the mid-scale readings will be at the 10-percent point on the chart. Thus, the recorder would be off as much as 10 percent from the true reading, yet still be within the recorder specifications (1 percent of full-scale accuracy). Proper mating and selection of scales is important. For resolution and accuracy, critical readings should

be recorded between 50 and 75 percent of full scale. Therefore, sources may request approval for monitoring systems that do not meet the specification. For example, some opacity monitors are set with full scale at 40 percent in order to obtain good mid-scale readings while the baghouse or precipitators are working. If the control device fails, these monitors would likely not read the actual emission value but would read 40 percent (the full-scale limit).

Most types of data handling equipment, from multipoint recorders to computer-controlled data acquisition systems, scan a number of analyzers with one set of electronic amplifiers, an analog to digital converter, and a single recorder for output. The frequency at which the scans are made can be selected. Even though opacity readings are taken once every 10 seconds, data systems may sample much more frequently in order to average out extreme readings and noise. High speed data systems at many chemical plants read 100 or more sensors per second. At this rate, the sample time is very short; thus, the noise peak part of the signal from an analyzer can be easily read. Average times of from 1/60th of a second or 1 hz or more are better suited for opacity monitoring. A continuous, integrated averager using 6-minute averaging periods would make the readings fully compatible with the reference method.

When using systems that rapidly scan all the analyzers, all individual readings need not be checked. However, one must be certain the software or mechanical programmer is scanning frequently enough and averaging its readings properly for the periods required (6 minutes or hourly). This is most easily checked by observing output during periods of change from zero to span calibration. It is also important (for purposes of correlating process with pollutant date) to average similarly, know (specifically) time of pollutant readings, and to permit easy collation of pollutant and process data. In addition, the outputs must always be identified for point/source of origin of signal, pollutant, time, day and most recent span/gain, calibrations, etc.

Accessories available with these data loggers range from 12-column printers to magnetic tape recorders, computer interfaces and typewriter-style printers. Now that the monitoring regulations have been promulgated

and the reporting requirements specified, we can expect that data logger vendors will make custom units available specifically for pollutant monitoring. These units will probably cost from $7,000 to $20,000, depending on the output required (column printer, magnetic tape, etc.).

The most automated approach incorporates a minicomputer into the system. This system could automate all routine functions of data acquisiton, calculation, and reporting as well as complete routine control of the monitoring system functions such as purge, zero, calibrate, and routine function checking. Although no such systems are marketed currently, custom systems of this type can be built on special order. One specific requirement of the purchase specifications is that the analyzer meet the performance specifications of the EPA Continuous Emission Monitoring regulations when outputs are connected to the data recorder and data reduction system the plant intends to use.

Reporting requirements will be discussed in more detail in later sections. Suffice it to say that a facility should select data handling equipment carefully. The level of data handling equipment that should be used will generally depend on the complexity of the monitoring situation (single versus multistack, one pollutant or many, etc.). However, simple, inexpensive systems will require considerable manpower to produce the required reports. An automated system will reduce manpower requirements but increase initial costs.

g. Meeting Regulation Requirements

The regulations place several key performance requirements on each system. Most of the requirememements -- such as accuracy, zero and span drift, range, and time response -- are simply defined and easily tested. Most vendors will state that their equipment meets these specifications. However, the source should make sure these statements and requirements are incorporated into a guarantee or warranty in the purchase documents. Manufacturer's literature is no substitute for demonstrated field experience.

In addition, vendors should be asked specific questions about how this equipment is designed to meet specific requirements. For example, paragraph (d) of 60.13 requires that the owner or operator must check the zero and span drift of a monitoring system at least once in each 24-hour period. Minimum

procedures are outlined in items (1) and (3) of the paragraph. Regardless of the vendor's representation that his equipment does not drift, the drift must be checked daily. Therefore, a system must be able to make these checks either manually or automatically when commanded by the operator.

Except for the Design Specifications for opacity monitors, all requirements placed on monitoring systems by Performance Specifications 1, 2, and 3 are checked specifically during the performance evaluation at each source. Thus, whether the monitor can or cannot meet the specifications must be specifically verified and demonstrated at each facility.

The only required vendor representation that becomes a matter of record is covered in Paragraphs 6.2 and 6.3 of Performance Specification 1. This paragraph allows a manufacturer to certify that his equipment complies with the requirements of Section 6 of the specification. In this case, the vendor must furnish a certification of testing, a description of test procedures, and the test results. This certification should contain a test procedure as detailed as that in Section 6.3 of Performance Specification 1 (opacity).

h. Level of Automation of Functions

Automation of many of the self-check functions in most monitoring systems is a relatively recent development. It has been stimulated greatly by the EPA stationary source monitoring requirements. We can expect that competition will force manufacturers to rapidly automate the more routine functions of both measurement and data reduction. In particular, systems may be controlled with microprocessors or microcomputers similar to these used in the new generation of electronic ovens.

4. Equipment Provisions for an Agency Observing and Verifying Data

There are no provisions on any monitors that will accomodate an Agency observer's equipment for routine checking. There are however, provisions and equipment for checking and maintenance that is available. This equipment would include any automatic or manual zero, span, or alignment check equipment, such as the optical alignment sight on the Lear Siegler RM-4 transmissometer or the span check filter on the DuPont 460 series gas montiors.

In extractive gas monitoring systems, although not a requirement, it should be easy for the source to provide an extra valve or fitting for the inspector to withdraw a sample from the probe or to introduce a calibration or test gas mixture into the probe. Similar fittings should be provided on the calibraion gas cylinders as well.

Systems with automated data recording can generally be checked with the source's own manual output devices (i.e., strip chart recorders) or with the observer's portable indicating or recording meters at the interface to the analyzer. If use of agency device is desired, the device must be electrically compatible with the source's system. During performance tests, the data flow to the final report should be described and calculations made in sufficient detail to demonstrate that the calculations correlate with the readings from the portable meters. During subsequent evaluations, the same procedure, test points, and equipment should be used to verify the validity of both the entire monitor system and of the automatic data processing subsystem.

It should be noted that Part 60.8(d) of the regulations requires safe sampling platforms, adequate sampling ports, safe access to sampling platforms, and utilities for sampling and testing. These facilities are required to evalutate the performance of the continuous monitoring system when it is first installed. They also would allow an agency to conduct comparison tests between the installed monitor and the sampling technique used as reference after the installation has been operational for several months. Providing for these facilities during initial construction is considerably less expensive than retrofitting them.

C. MONITOR LOCATION

1. Regulations

Paragraph (f) of Section 60.13 of the regulations requires that the monitoring systems be located to measure representative emissions or process parameters from the source.

> (f) All continuous monitoring systems or monitoring devices shall be installed such that representative measurements of emissions or

process parameters from the affected facility are obtained. Additional procedures for location of continuous monitoring systems contained in the applicable Performance Specifications of Appendix B of this part shall be used.

Each performance specification includes specific installation requirements for the type of measurement (opacity, SO_2, etc.) and the type of equipment to be used (in situ, extractive). Subsection B, which follows, discusses the requirements in Performance specification 1 for opacity monitors. Subsection C discusses the corresponding requirements in Performance Specification 2 for measuring gaseous emissions.

2. Installation Specification for Opacity Monitoring Systems

The installation specifications in Section 4 of Performance Specification 1 include the following:

4. Installation Specification

4.1 Location. The transmissometer must be located across a section of duct or stack that will provide a particulate matter flow through the optical volume of the transmissometer that is representative of the particulate matter flow through the duct or stack. It is recommended that the monitor path length or depth of effluent for the transmissometer include the entire diameter of the duct or stack. In installations using a shorter path length, extra caution must be used in determining the measurement location representative of the particulate matter flow through the duct or stack.

4.1.1 The transmissometer location shall be downstream from all particulate control equipment.

4.1.2 The transmissometer shall be located as far from bends and obstructions as practical.

4.1.3 A transmissometer that is located in the duct or stack following a bend shall be installed in the plane defined by the bend where possible.

4.1.4 The transmissometer should be installed in an accessible location.

a. Representative Effluent

The problems in measuring opacity come from trying to measure one phase of material (liquid or solid) suspended in another phase (gas). This results in nonhomogeneous mixing, stratification due to gravity, segregation due to aerodynamic or centrifugal forces in bends, etc. In measuring particulate loadings using EPA Method 5, the effect of this maldistribution can be corrected for by an extensive traversing scheme. When installing an opacity monitor, however, it is not possible to provide a traversing mechanism or equivalent, so that special care must be taken in examining and selecting the monitoring site.

As a general rule, the transmissometer used to measure opacity should be installed in a round, vertical stack rather than a horizontal, rectangular duct whenever possible. This is because rectangular ducts tend to have a less uniform particulate concentration than round ones. As shown in Figure 1-13, the distribution of particulate matter from the top of a horizontal rectangular duct varies widely. Settling due to gravity causes some of this stratification, and large particles, high or low gas velocities, or small radius of curvature can make stratification worse. The use of flow straighteners and the number and abruptness of bends in the duct also affect the distribution of particulate.

Besides horizontal rectangular ducts, sources should also avoid sharp bends in ducts without corrective devices. As Figure 1-14 shows, with sharp bends and high velocities, the gas flow can separate from the duct wall for several diameters, forming recirculation zones and causing dust to deposit in the ductwork. These conditions can also occur in ducts that diverge too rapidly.

If the Agency believes that the transmissometer being used by a source does not measure a representative portion of the emission stream, the owner of a source may be asked to demonstrate that the selected measuring location is representative for maximum or varying operating rates. This is clearly stated in Section 4.1.5:

> 4.1.5 When required by the Administrator, the owner or operator of a source must demonstrate that the transmissometer is located

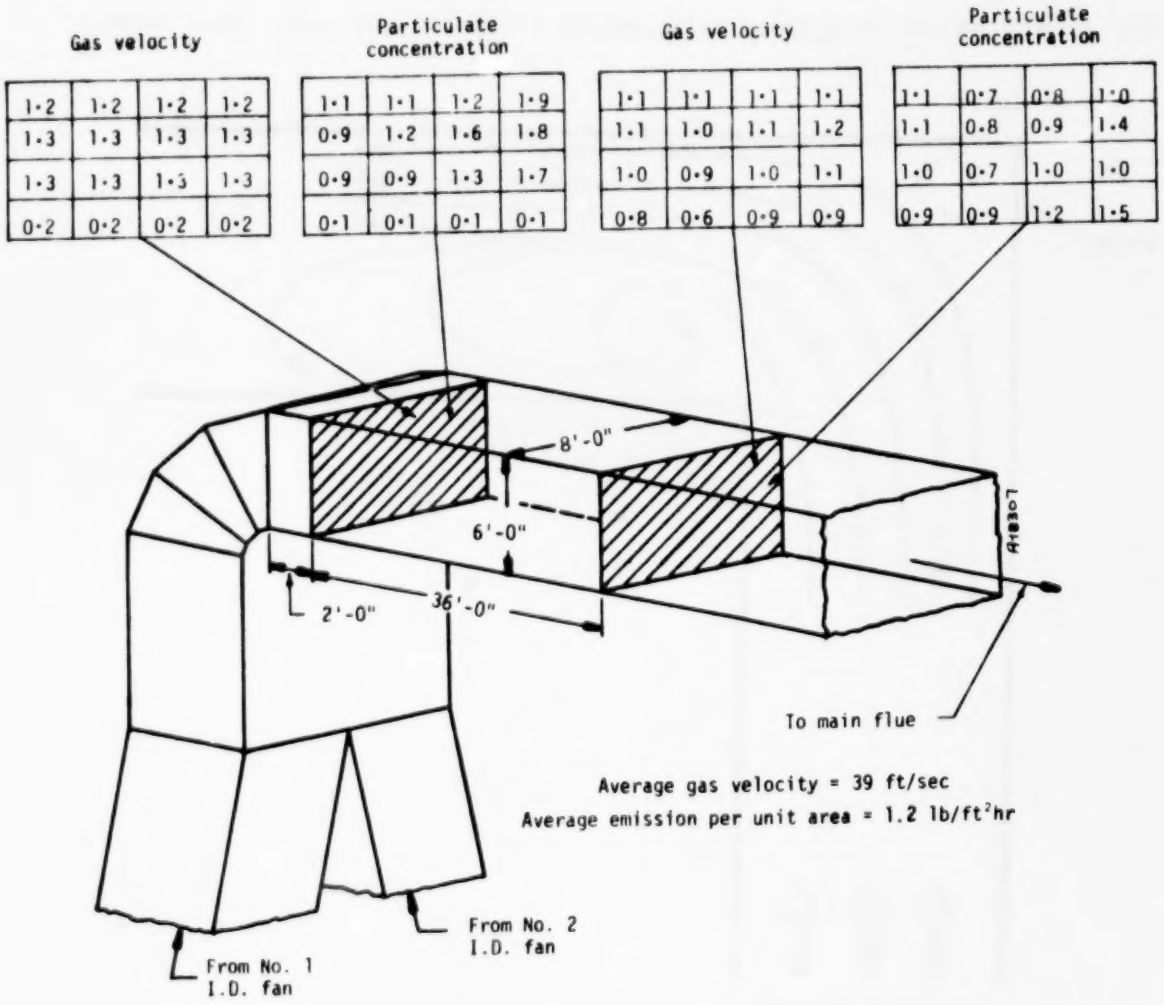

Figure 1-13. Velocity and particulate distribution in a rectangular duct.

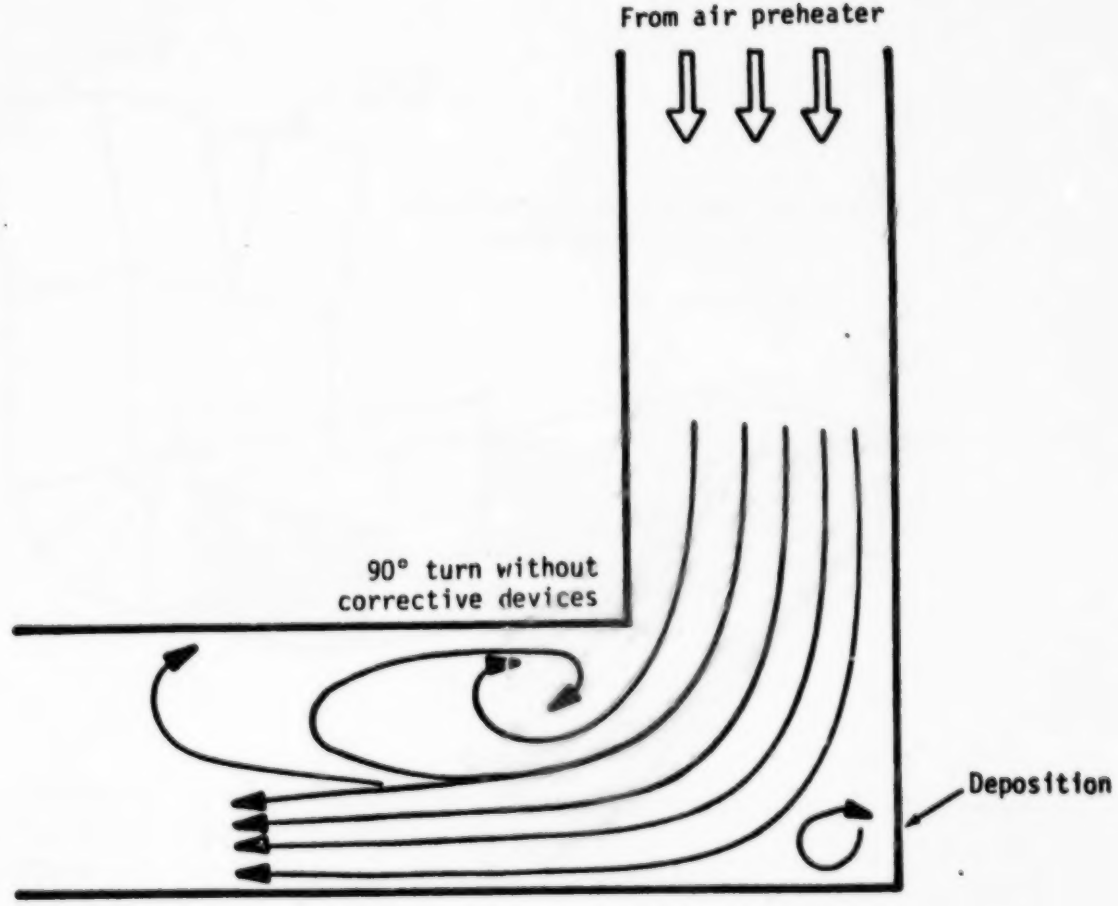

Figure 1-14. Flow recirculation and particle deposition in rectangular duct.

in a section of duct or stack where a representative particulate matter distribution exists. The determination shall be accomplished by examining the opacity profile of the effluent at a series of positions across the duct or stack while the plant is in operation at maximum or reduced operating rates or by other tests acceptable to the Administrator.

When a source installs the transmissometer, ports should be provided at several different positions on a rectangular duct so that an opacity profile can be made of the duct. For a round stack, two ports at 90° from each other will usually be sufficient. The transmissometer must not be installed in ports used for particulate and gaseous sampling. It should, in fact, have its own separate set of ports. This will prevent the need for removing the transmissometer during manual sampling for gases or particulates. Care must be taken in locating these ports to avoid flow disturbances caused by other sample ports and sampling apparatus. The regulations require the source to install the transmissometer in an "accessible location." Far too frequently, "accessible" is understood to mean "convenient," and little attention is paid to whether or not the location will give a representative sample. In fact, what is most important is that the transmissometer be located in a representative section of duct or stack. Once this location is established, safe, convenient access should be provided (OSHA approved elevators, manlifts, ladders, sheltered platforms, railings, etc.). This will ensure that the instrument gets regular inspection and maintenance.

b. Multiple Feed Points

Paragraph (g) of Section 60.13 requires that each separate emission stream be monitored, with the following exceptions:

(g) When the effluents from a single affected facility or two or more affected facilities subject to the same emission standards are combined before being released to the atmosphere, the owner or operator may install applicable continuous monitoring systems on each effluent or on the combined effluent. When the affected facilities are not subject to the same emission standards, separate

> Continuous monitoring systems shall be installed on each effluent. When the effluent from one affected facility is released to the atmosphere through more than one point, the owner or operator shall install applicable continuous monitoring systems on each separate effluent unless the installation of fewer systems is approved by the Administrator.

Take, for example the core of a coal fired power plant with two or more boiler feeding into a single, common stack. If all boilers are subject to NSPS, then only the common stack need be monitored. However, if any one of the boilers feeding that stack is not subject to NSPS, then each of the other boilers that are subject to NSPS must be monitored separately. If individual monitors are installed on three boilers, the installation standards in Performance Specification 1 will apply.

c. Stratification

In stratification, flowstream components move in layers or concentration bands (i.e., nonuniform pollutant or flow distributions) in the duct. For example, as shown in Figure 1-13, the larger particulate will tend to move toward the bottom of a large horizontal duct because of higher settling rates. Similarly, large particulate is generally forced toward the outside of a bend in a duct by centrifugal forces. These conditions can occur in most duct configurations. Unless action is taken to remix these "layers," the particulate is likely to remain stratified. This will make it difficult to select a representative monitoring point. Because stratification involves mainly large rather than fine particulate -- and since due to population densities, large particulate has only a minor effect on opacity -- stratification is not a critical factor in opacity monitoring.

Short of intuitive judgement by people experienced with locating transmissometers, there is only one reliable way to determine if particulate stratification exists in a duct: manual testing methods for gas velocity and for particulate concentrations on a point-by-level basis must be performed on a duct cross section. If velocities vary significantly across the duct, it is likely that stratification exists. Particulate sampling at numerous points in the duct (as defined by EPA Reference Method 1) will, of course, best show if stratification exists.

d. Condensed Water

Condensed water is the most serious problem in making accurate opacity measurements. The opacity of an effluent is a direct measurement of the attenuation of visible radiation by particulate matter in the stream. Since water droplets attenuate light in the same way as solid particles, opacity cannot be accurately measured by conventional monitoring systems when condensed water vapor is a major constituent of the effluent.

A source can tell how much condensed water vapor is in the effluent by determining moisture content (by volume) using two methods. They are: (1) EPA Reference Method 4 -- Part 60, Appendix A and (2) psychrometry -- assuming that the effluent is a saturated vapor. If Method 4 yields a higher moisture content than the psychrometry method, the difference can be assumed to be condensed water vapor.

Paragraph (i) of Part 60.13 allows a source to request and the Administrator to approve alternative monitoring requirements when interference caused by liquid water (not a high concentration of water vapor) or other substances make accurate opacity measurements impossible.

> (i) Upon written application by an owner or operator, the Administrator may approve alternatives to any monitoring procedures or requirements of this part including, but not limited to the following:
>
> (1) Alternative monitoring requirements when installation of a continuous monitoring system or monitoring device specified by this part would not provide accurate measurements due to liquid water or other interferences caused by substances with the effluent gases.

In some cases it may be possible to move the monitor to another location in the flue system where the stack gas temperature is above its dewpoint. This will eliminate attenuation of visible radiation by condensed water droplets. However, this solution is probably not possible in most installations. For instance, very few wet scrubbers are equipped with flue gas reheat capabilities to eliminate the visible steam plume. Furthermore, even though a stack may be above its dewpoint in the hot summer months, it

will often be below its dewpoint in the winter. This problem is particularly severe in stacks with relatively low temperatures (<200°F) and uninsulated stack walls. Consequently, in a case where opacity measurements are affected by water droplets, the facility and the Agency will have to agree upon the monitoring of some other parameter to characterize control device efficiency (i.e., scrubber pressure drop).

e. Installation and Maintenance Considerations

Since opacity monitors must have a narrow field of view, installation and alignment are often a problem. Field experiments performed by EPA show that the thermal expansion and contraction of steel stacks and ducts caused by unit load cycling, startup/shutdown, or weather conditions is sufficient to throw the alignment of the transmissometer out of tolerance. To minimize the effects of misalignment, 40 FR4626 Appendix B, Performance Spec. 1, 8.2.1, requires annual optical and zero alignment during a plant shutdown. Concrete or brick stacks do not generally experience this problem due to a negligible thermal response.

A monitor, or any of its optical components (reflectors, sources), should be located on a rigid section of duct or stack or even mounted independently so that the alignment will not be seriously affected by thermal expansion. An independent mounting may be required when the stack is vibrating heavily or is quite hot (<400°F), since radiaiton from the walls will affect the measurement.

The monitor should be located in a clean, sheltered, readily accessible area. The easier it becomes for a maintenance technician to check blower filters, dirty windows, dirty retroreflectors, alignment, etc., the more likely it is that maintenance will be done on a regular basis. The most serious operating problem with opacity monitors is generally keeping the optical windows and other components clean. Many, but not all, manufacturers offer high volume blowers that blow 40 to 60 cfm of clean air across the optical windows. The use of this type of blower is almost mandatory. Note that positive pressure stacks may seriously affect blower capacity.

3. Installation Specification for Gaseous and Diluent Emission Monitoring Systems

The primary specifications for installing gaseous emission measuring equipment are contained in Section 4 of Performance Specification 2:

> 4. Installation Specification. Pollutant continuous monitoring systems (SO_2 and NO_x) shall be installed at a sampling location where measurements can be made which are directly representative (4.1), or which can be corrected so as to be representative (4.2) of the total emissions from the affected facility.

As explained in the following paragraphs, there are several important differences between this specification and the corresponding specification for opacity monitoring. In addition, further regulations in Part 60 are very specific in regards to individual sources or groups of sources.

a. Representative Effluent

In contrast to opacity monitoring, gaseous emissions monitoring is concerned only with measuring the gaseous phase. Solids or liquids may be eliminated or separated from the gas stream during this measurement if required. Also, since once the gas stream is mixed, it will remain homogenous, stratification caused by gravity, aerodynamics, or centrifugal forces which affect particulate measurements rarely affect gas measurement. As a result, the major problems with gaseous monitoring are poor initial mixing of the various gases in the stream and in-leakage of air into the ducts.

Paragraph 4.1 of Performance Specification 2 deals with the problem of in-leakage:

> 4.1 Effluent gases may be assumed to be nonstratified if a sampling location of eight or more stack diameters (equivalent diameters) downstream of any air in-leakage is selected. This assumption and data correction procedures under Paragraph 4.2.1 may not be applied to sampling locations upstream of an air preheater in a steam generating facility under Subpart D of the part. For sampling locations where effluent gases are either demonstrated

(4.3) or may be assumed to be nonstratified (eight diameters), a point (extractive systems) or path (in situ systems) of average concentration may be monitored.

A number of EPA programs have shown that considerable air leakage occurs in air preheaters in steam generating facilities. Therefore, gas concentrations should only be assumed to be homogeneous if there are eight or more duct diameters downstream of the air preheaters. This assumption is not applicable to sampling locations upstream of an air-preheater, nor is it applicable to paragraph 4.2.1 of Performance Specification 2, because a diluent monitor may not be installed upstream of the largest source of air in-leakage -- the air-preheater. A multipoint probe coupled to an extractive system or an in situ system must be used for gaseous monitoring as explained in Paragrpah 4.2.2 below. The Administrator may also require additional data to prove that the monitoring system data is consistently representative for various process operating conditions.

4.2 For sampling locations where effluent gases cannot be assumed to be nonstratified (less than eight diameters) or have been shown under paragraph 4.3 to be stratified, results obtained must be consistently representative (e.g. a point of average concentration may shift with load changes) or the data generated by sampling at a point (extractive systems) or across a path (in situ systems) must be corrected (4.2.1 and 4.2.2) so as to be representative of the total emissions from the affected facility. Conformance with this requirement may be accomplished in either of the following ways:

4.2.1 Installation of a diluent continuous monitoring system (O_2 or CO_2 as applicable) in accordance with the procedures under paragraph 4.2 of Performance Specification 3 of this appendix. If the pollutant and diluent monitoring systems are not of the same type (both extractive or both in situ), the extractive system must use a multipoint probe.

4.2.2 Installation of extractive pollutant monitoring systems using multipoint sampling probes or in situ pollutant monitoring systems that sample or view emissions which are consistently representative of the total emissions for the entire cross section. The Administrator may require data to be submitted to demonstrate that the emissions sampled or viewed are consistently representative for several typical facility process operating conditions.

An extractive or in situ monitoring system should be installed in its own sampling port(s) rather than in ports used for manual particulate and gaseous sampling. Separate ports are required for the performance test of the monitoring system or for concurrent manual sampling. As with opacity monitors, adequate sheltered sampling platforms, ladders, electrical power outlets, etc., should be installed to provide convenient access to the monitoring location.

Prior to a late 1975 study by the Emission Measurement Branch of the Office of Air Quality Planning and Standards, it was commonly thought that alkaline scrubber fluids in most flue gas desulfurization systems alter the CO_2 concentration, thereby affecting downstream CO_2 measurements. The Federal Register Part 60.45 (b) (3) (i-iii) reflected this assumption, since if CO_2 was used to correct the emission measurements to the units of the standard, the source was required to locate the CO_2 monitor upstream of the scrubber. In response to the EMB study findings, 42FR5936-1/31/77 deleted this requirement on the location of CO_2 monitors where flue gas desulfuriztion is used. However, since there is a possibility of CO_2 production from reactions in a limestone scrubber, when this type of FGD device is used a 1-percent increase in the F_c factor is required.

If a different fuel from that used in the boiler is fired directly into the flue gas for any purpose (e.g., reheating), the pollutant (e.g., SO_2), opacity, CO_2, or O_2 continuous monitoring system must be installed downstream of this location.

b. Multiple Feed Points

As noted in Section (g) of Part 60.13, a single monitoring system may be used to measure the combined effluent from several facilities if all facilities are subject to the same standard. If there are multiple emission points from one facility, separate monitoring systems are required unless an alternative method is specifically approved by the Administrator. In the case of gases, extractive systems that can sequentially sample multiple locations are available. As long as the basic cycle time of these systems is consistent with the 15-minute maximum (Section (e)(2) or 60.13), a single system may be used to sample several feed points. Multipoint systems are available from most major extractive equipment manufacturers.

c. Stratification.

Stratification of gaseous pollutants has not been as universally accepted as it has been for particulate matter. In fact, it is commonly believed that there is no gas stratification in ducts with turbulent gas flow. In reality, stratification of pollutant species due to poor initial mixing and air infiltration commonly occurs. Figure 1-15 shows an example of SO_2 stratification in a large rectangular duct at a coal fired power plant. Paragraphs 4.2 and 4.3 of Performance Specification 2 place specific requirements on the sampling locations where stratification has been demonstrated or may be presumed to exist:

4.2 For sampling locations where effluent gases cannot be assumed to be nonstratified (less than eight diameters) or have been shown under Paragraph 4.3 to be stratified, results obtained must be consistently representative (e.g., a point of average concentration may shift with load changed) or the data generated by sampling at a point (extractive systems) or across a path (in situ systems) must be corrected (4.2.1 and 4.2.2) so as to be representative of the total emissions from the affected facility. Conformance with this requirement may be accomplished in either of the following ways:

4.2.1 Installation of a diluent continuous monitoring system (O_2 or CO_2 as applicable) in accordance with the procedures under

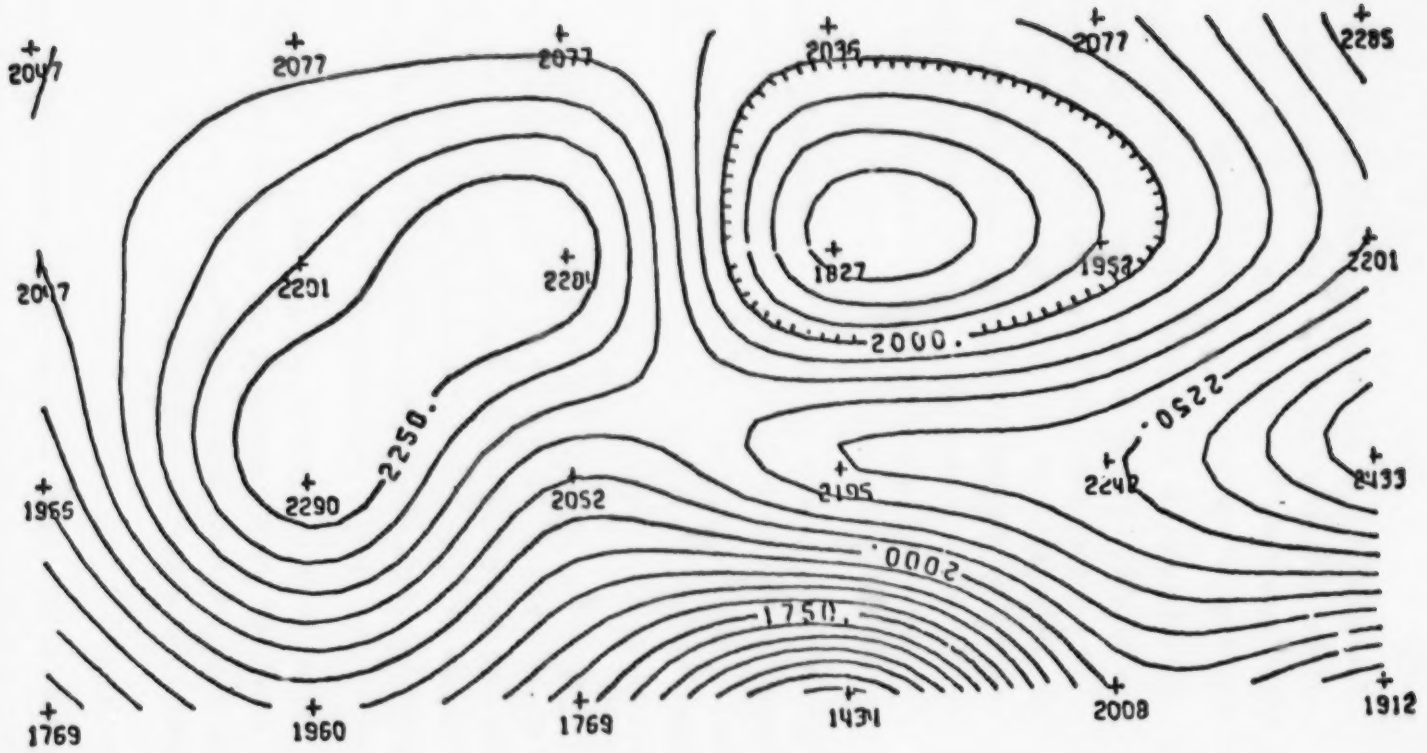

Figure 1-15. Stratification due to poor initial mixing SO_2 concentration (ppm) in a rectangular duct.

Paragraph 4.2 of Performance Specification 3 of the appendix. If the pollutant and diluent monitoring systems are not of the same type (both extractive or both in situ), the extractive system must use a multipoint probe.

4.2.2 Installation of extractive pollutant monitoring systems using multipoint sampling probes or in situ pollutant monitoring systems that sample or view emissions which are consistently representative of the total emissions for the entire cross section. The Administrator may require data to be submitted to demonstrate that the emissions sampled or viewed are consistently representative for several typical facility process operating conditions.

4.3 The owner or operator may perform a traverse to characterize any stratification or effluent gases that might exist in a stack or duct. If no stratification is present, sampling procedures under Paragraph 4.1 may be applied even though the eight diameter criterion is not met.

4.4 When single point sampling probes for extractive systems are installed within the stack or duct under Paragraphs 4.1 and 4.2.1, the sample may not be extracted at any point less than 1.0 meter from the stack or duct wall. Multipoint sampling probes installed under Paragraph 4.2.2 may be located at any points necessary to obtain consistently representative samples.

As explained in Paragraph 4.3, a plant operator may perform manual traverses to show that the gas stream is not stratified at a particular sampling location. Traverses using a continuous O_2 or CO_2 analyzer can quickly determine the extent of stratification.

d. Dilution

Paragraph (d) of Part 60.45 requires the installation (generally in close proximity to pollutant monitor probe inlet) of either a carbon dioxide or an oxygen continuous monitoring system at each steam generating facility (exceptions are noted in Section I(B)(1)). The data from these systems is

used to correct the emission values from the SO_2 and NO_x measurement system for the dilution effects of excess air and air in-leakage from preheaters, etc. The use of these corrections is discussed in Section III.C.5. Oxygen and carbon dioxide measurement systems are subject to Performance Specification 3.

41FR44838 cites the approval of alternative monitoring procedures provided for by 60.13(i)(3). Restrictions on wet basis diluent and pollutant measurements have been removed. Specifically, approval has been given for alternative emission data reduction procedures to be used with wet-basis stack gas pollutant and oxygen monitoring data from fossil fuel-fired steam generators. The approved alternative data reduction procedures have been detailed in 41FR44838.

e. Accessibility for Agency Inspection and Source Maintenance

The regulations for inspecting continuous monitoring systems and monitoring devices are contained in Section 114 of the Clean Air Act amendments of 1970:

Section 114(a)

(2) the administrator or his authorized representative, upon presentation of his credentials --

(a) shall have a right of entry to, upon, or through any premises in which an emission source is located or in which any records required to be maintained under Paragraph (1) of this section are located, and

(b) may at reasonable times have access to and copy any records, inspect any monitoring equipment or method required under Paragraph (1), and sample any emissions which the owner or operator of such a source is required to sample under Paragraph (1).

Unlike Performance Specification 1, which states, "4.1.4 The transmissometer should be installed in an accessible location," Performance Specification 2 (SO_2 and NO_x) and Performance Specification 3 (CO_2 and O_2)

do not place any particular requirements on accessibility of the systems. However, as discussed in the opacity maintenance section, the key to an effective monitoring operation is maintenance, daily operating checks and weekly periodic maintenance. The EPA evaluation programs are full of examples where systems down for a week or more could have remained operational with 5 minutes of maintenance. Furthermore, almost all problems could have been easily recognized by even a casual daily inspection that included a zero and span calibration check. This experience clearly shows that a monitoring system must be readily accessible to receive the daily maintenance and care necessary to operate effectively. Therefore, even though the performance specifications for gaseous monitors do not specifically require an accessible location, the evaluator should strongly recommend one.

D. CONTINUOUS MONITORING SYSTEM SELECTION AND LOCATION CHECKLISTS

This section contains checklists to be used as an aide to the agency observer when assisting with and evaluating the selection and location of a source's continuous monitoring system. Each question in the checklists has been referenced to the appropriate part of the Manual text.

SELECTION OF MONITORING EQUIPMENT CHECKLIST

	Subsection References	Yes	No	N.A.	Notes
1. Opacity					
• Is the system double or single ended?	B.2.a				
• Is the measurement path length the same as the stack exit diameter?	B.2.a				
• How is the unit calibrated?	B.2.a				
• Does the unit have an alignment check?	B.2.a				
• Does the unit have automatic calibration features?	B.2.a				
• Does the unit have any type of malfunction?	B.2.a				
• Does the unit have automatic zero adjustment features?	B.2.a				
• Does the unit have any type of malfunction indicators? (lamps, meters, alarms)	B.2.a				
• Is the unit certified to meet the spectral response and field of new requirements of Performance Specification 1?	B.2.a				
• What window cleaning is required?	B.2.a				
• Does the unit have window purge accessories?	B.2.a				

SELECTION OF MONITORING EQUIPMENT CHECKLIST (Continued)

	Subsection References	Yes	No	N.A.	Notes
• Does the unit have a visual output for the operator? (meter, strip chart)	B.2.a				
• Is the unit equipped with any excess emissions indicators? (lights, bells, horns)	B.2.a				
2. Gaseous Emission Monitoring Equipment					
• Which gas is to be measured?	B.3.b.i				
• What concentrations?	B.3.b.i				
• Do the emission levels vary widely (3/1 or greater) with time or plant input?	B.3.b.i				
• What are the controlled versus uncontrolled emissions?	B.3.b.ix				
• Are appreciable amount of water vapor present (about 1 percent)?	B.3.b.iii				
• Is there any condensed water or other chemical droplets?					
• Is multiple stack sampling desirable?	B.3.b.vi				
• Do several streams feed into one stack?	B.3.b.vi				
• Does the stack also have particulate emissions?	B.3.b.iv				
• How well are particulate emissions controlled?	B.3.b.iv				

SELECTION OF MONITORING EQUIPMENT CHECKLIST (Continued)

	Subsection References	Yes	No	N.A.	Notes
• Does the sampling system require water removal?	B.3.b.iii				
• Were specific tests made to select the sampling location?	B.3.b.ii				
• Does the temperature or pressure vary at the sampling location?	B.3.b.vii				
• Does the monitoring system compensate for power line variations?	B.3.b.viii				
• Does the unit have automatic or manual "zero" capability?	B.3.a				
• Does the unit have any type of output display for the operator?	B.3.a				
• Does the unit read out in concentrations, corrected or uncorrected for dilution air?	B.3.e				
• Is there an excess emissions warning device?	B.3.c				
• When were calibration gas cells last checked?	B.3.g				
• Has the instrument been calibrated over all potential operating ranges?	B.3.g				
3. Data Recording and Reduction Equipment					
• What is the frequency of system analysis and recording?	B.3.g				

SELECTION OF MONITORING EQUIPMENT CHECKLIST (Concluded)

	Subsection References	Yes	No	N.A.	Notes
• What is the method used for averaging?	B.3.g				
– Six-minute averages?					
– Hourly averages?					
• How is time of SO_2 readings correlated with CO readings for excess air conversion?	B.3.g				
• How is the date and time recorded?	B.3.g				
• What is the data recorder resolution and accuracy?	B.3.g				
• What is the chart speed?	B.3.g				
• Does the recorder display have a zero offset or is the chart zero 5 percent of scale?					
• What are the units of the recordings?	B.3.g				
• Is the software and system data flow well documented and demonstratable?	B.3.g				
• How are frequency and time of process and monitoring system malfunctions documented?	B.3.g				
• Who is responsible for reducing data and preparing reports?	B.3.g				

MONITOR LOCATION CHECKLIST

	Subsection References	Yes	No	N.A.	Notes
1. Sampling Location					
• Does more than one unit share a stack?	C.2.b				
• What standards apply to each unit?	C.2.b				
• How are combined effluent records kept?	C.2.b				
2. Opacity Measurements					
• Does the monitor view across the entire duct or a portion?	C.2				
• Is the unit downstream of all particulate control equipment?	C.2				
• Is the unit too near any ducting bends, obstructions, transitions?	C.2				
• If the unit is near a bend, does it measure in the plane of the bend?	C.2				
• Is the unit readily accessible?	C.2				
• Is dilution air added to the stack?	C.2				
• Is the monitor at the end of a long straight duct?	C.2				
• Is the dust velocity below 30 feet per second?					

MONITOR LOCATION CHECKLIST (Continued)

	Subsection References	Yes	No	N.A.	Notes
• Does the flow velocity vary with plant output variations?	C.2.a				
• Does the opacity vary with plant output?	C.2.a				
• Are condensed water or other liquid mists present?	C.2.d				
• Is stratification evident?	C.2.c				
3. Gaseous Measurements					
• Is the monitor downstream of all control equipment?	C.3				
• Is the sampling location eight or more diameters downstream of any air in-leakage?	C.3.a				
• Is dilution air added to the stack?	C.3.a				
• Does an extractive monitor use single or multiple point sampling?	C.3.c				
• Does an in situ monitor view the entire cross section or a limited portion?	C.3.a				
• Does the gas concentration, dilution, or in-leakage vary with plant output?	C.3.a				
• Is the monitor readily accessible?	C.3.a				

MONITOR LOCATION CHECKLIST (Concluded)

	Subsection References	Yes	No	N.A.	Notes
• Is a flue gas scrubber system installed?	C.3.a				
• Is CO_2 or oxygen monitored?	C.3.a				
• Are different fuels fired?	C.3.a				
• Is stack reheating used?	C.3.a				
• Are multiple sources fed into one stack?	C.3.b				
• Does the monitoring system measure more than one stack?	C.3.b				
• If so, is each stack sampled at least once every 15 minutes?	C.3.b				

REFERENCES: SOURCE MONITORING EVALUATION PROGRAMS

1. Evaluation of Monitoring Methods and Instrumentation for Hydrocarbons and CO in Stationary Source Emissions: EPA-R2-72-106.
2. Monitoring Instrumentation for the Measurement of SO_2 in Stationary Source Emissions: EPA-R2-73-163.
3. Instrumentation for the Determination of NO_x Content of Stationary Source Emissions: APTD-0847 and APTD-0942.
4. Measurement of the Opacity and Mass Concentration of Particulate Emissions by Transmissometry: EPA-650/2-74-128.
5. Performance Specifications for Stationary Source Monitoring Systems for Gases and Visible Emissions: EPA-650/2-74-103.
6. Continuous Measurement of Gas Composition from Stationary Sources: EPA-600/2-75-053 a,b.
7. Field Evaluation of SO_2 Monitoring Systems Applied to H_2SO_4 Plant Emissions: EPA-650/2-75-053 a,b.
8. Instrumentation for Environmental Monitoring: Lawrence Berkeley Laboratory, University of California.
9. Evaluation of Sample Conditioners and Continuous Stack Monitors for the Measurement of SO_2, NO_x, and Opacity in Flue Gas from a Coal-fired Steam Generator: Sourthern Services, Inc., Birmingham, Alabama.